

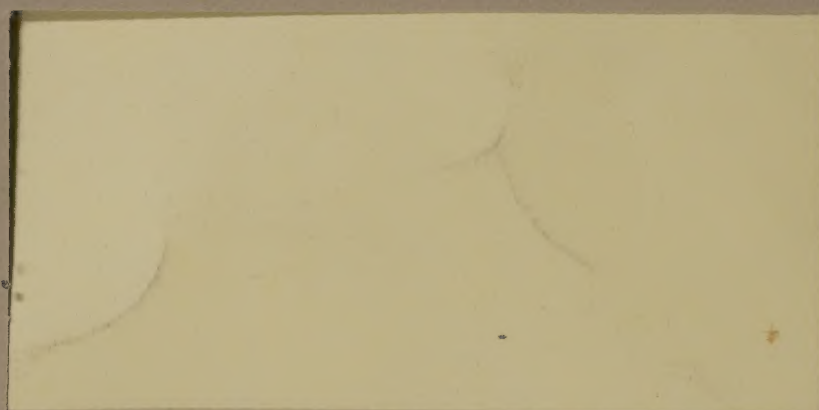
IMPACT ANALYSIS OF THE SCREWORM
ADULT SUPPRESSION SYSTEM (SWASS)

PHASE III REPORT

KTR 170-80

25 AUGUST 1980

KETRON, INC.



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EXECUTIVE SUMMARY

This report presents the results of an impact assessment of the Screwworm Adult Suppression System (SWASS), a bait-toxicant pesticide system developed by the Veterinary Services of APHIS, USDA in order to facilitate the eradication of the screwworm (Cochliomyia hominivorax), a serious pest of livestock in the United States and Mexico.

The impact assessment is in two parts: an environmental assessment of the use of SWASS and an economic analysis of SWASS as a component of the overall screwworm program.

The procedures and results from this environmental assessment are to be the foundation upon which future assessments of environmental impact in Mexico will be based. To facilitate the application of the results of this assessment to Mexico, three ecological regions in the southwestern United States were chosen which are representative of areas in northern Mexico where SWASS would first be used. SWASS is employed in response to a significant number of reported screwworm cases or a significant number of wild screwworm flies caught in traps. Thus, it is impossible to know in advance when or where SWASS might be used. For this reason, it was assumed that SWASS might be applied anywhere in any of the three representative regions.

SWASS is formulated as pellets, with the components as follows: an organophosphate insecticide of high volatility, DDVP (dichlorvos, Vapona); a chemical attractant composed of ten naturally occurring compounds, called swormlure-2; and bait materials of dried blood, sugar, corn cob grits, and KSL wax.

The half-life of DDVP in SWASS pellets is about two days, and the half-life of swormlure is one to two days. DDVP is rapidly hydrolyzed in the air. SWASS chemicals will not accumulate in the soil, and the half-life of DDVP in soil is probably less than a week.

The transport of SWASS chemicals by runoff into streams is extremely unlikely; should DDVP be transported into a stream, lake, or estuary, the concentration in the water would be negligible. The amount of toxicant in a SWASS pellet is so small that even with successive misapplications to small ponds or cattle tanks, the concentration of DDVP in water will be very small, probably less than 0.1 ppb.

The environmental effects of SWASS were found to be as follows.

Water fleas, which are minute crustacean zooplankton, are extremely sensitive to DDVP, and some mortality might be expected with inadvertent application of a pellet to a small pond or cattle tank. However, because most zooplankton are more tolerant, no effects are expected on aquatic food webs. Concentrations of DDVP in lakes, streams, and estuaries are expected to be below the median lethal concentrations (LC_{50} 's) for all zooplankton.

When applied in accordance with its restrictions, SWASS will have no effects on phytoplankton, aquatic arthropods, mollusks, or aquatic vertebrates.

No residues of DDVP are expected in fish or any other fisheries products. Even with several inadvertent applications of SWASS pellets to a fishpond, residues of the most toxic swormlure chemicals in fish (phenol and p-cresol) would still be less than 1 ppb. Residues in fisheries products from streams, lakes, or estuaries would be negligible. Swormlure residues in aquatic organisms are transient.

When applied in accordance with its restrictions, SWASS will have no effects on aquatic endangered or threatened species.

Some mortality of soil organisms would be expected from the use of SWASS, but effects will occur only in the immediate vicinity of the pellets (within 50 cm). Given the wide dispersion of the pellets, these effects will be insignificant.

There will be some mortality of non-target insects, primarily Diptera in the families Calliphoridae, Sarcophagidae, and Muscidae, many of which are considered pest species. Effects on these species should be short-term. Bees are not expected to be affected.

Because populations of non-target insects should not be significantly affected by the use of SWASS, no indirect effects are expected on insectivorous species.

There is the potential for mortality to small mammals which might ingest SWASS pellets. Those species most at risk are small scavenging rodents such as cotton rats and wood rats. It is expected that mortality would be an isolated occurrence and that populations would not be affected. Scavenging carnivores and omnivores might be attracted to SWASS pellets, but their size and relative resistance to DDVP are such that ingestion of a SWASS pellet would not normally be lethal. No effects are expected on livestock, grazing wildlife, birds, or reptiles.

No residues of DDVP or swormlure are expected in the meat of cattle, sheep, goats, grazing wildlife, poultry, or game birds, or in milk and eggs. Pigs, javelinas, and rabbits might ingest SWASS pellets but because of the rapid metabolism of DDVP and the swormlure chemicals, residues in the meat of these species will be negligible.

The use of SWASS is expected to have no effects on members of endangered or threatened terrestrial species.

Exposure of humans to SWASS chemicals through inhalation or residues in food and water will be insignificant. The only mechanism for exposure of humans to significant quantities of SWASS chemicals is direct ingestion of a pellet. Because SWASS is applied only in sparsely inhabited rangeland, because its odor is very disagreeable, and the amount of DDVP in a pellet is small, the risk to humans from the use of SWASS appears negligible.

No research or resource program conflicts were identified during telephone investigations with program personnel. It was found that most people do not distinguish between the effects of SWASS and the sterile fly release program.

The SWASS pellets should not create any perceivable change in the physical surroundings of the general public, and the accidental application of SWASS would not cause perceivable impacts on the aquatic environment, water quality, or aquatic organisms.

The SWASS treatment programs may be perceived to be more acceptable than the sterile fly release program because it would decrease the number of flies immediately whereas the sterile fly release program initially increases the number of flies by adding the sterile males to the wild screwworm fly populations. General well-being may be perceived to be increased because there are fewer flies immediately.

The economic analysis of SWASS was conducted on two levels: small area and large area. The small area analysis considered individual applications of sterile flies and SWASS was done for areas of one square mile. The large area analysis looked at SWASS as a supplement to the sterile fly program and considered the long-term effect on the movement of the sterile fly barrier as a result of using SWASS.

After a thorough analysis of SWASS and the screwworm population dynamics model, it was concluded that SWASS is a cost effective addition to the sterile fly technique in controlling small

area native populations with large populations or high growth rates. Furthermore, it is felt that SWASS may be the only practical means presently available of controlling some few intense small area outbreaks unless extraordinarily high numbers of sterile flies would be feasible on a per square mile basis.

It also appears that for most moderate or even some small populations of native flies the use of SWASS is theoretically cost effective. However, the use of SWASS in such cases might not be practical (1) because of the overall supply of SWASS pellets, the difficulties of determining native populations, the lack of significant differences in costs and effectiveness between SWASS/sterile male programs and sterile male alone programs needed for such native population levels and (2) because of the potential for increased administrative burden which would arise if decisions concerning SWASS usage for multitudes of small areas had to be made and carried out in daily operations.

The recommendation was made that relatively simple procedures for determining SWASS usage be developed which could be easily administered and which would guarantee that SWASS be used in the important heavy infestations. In such uses SWASS is necessary and certain to be cost effective. In this way, SWASS could be used to support the orderly movement of the sterile fly barrier to its planned new position.

The large area analysis also provided support for the cost effectiveness of SWASS usage. Using the opinions of many experts polled, it was concluded that SWASS used as planned could provide a significant reduction in the time needed to move the barrier into place in southern Mexico and because of this reduction in time is likely to save the United States significant costs of program operations.

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CHAPTER 1

INTRODUCTION AND BACKGROUND

1.0 Introduction

The Screwworm Adult Suppression System (SWASS) is a bait-toxicant pesticide system developed by the Veterinary Services of APHIS, USDA, to facilitate the eradication of the screwworm (Cochliomyia hominivorax), a serious pest of livestock in the southwestern United States and Mexico.

This Phase III report is the third of a series of reports in the environmental and economic impact assessment of the SWASS program. Phase I was a pre-design study to determine the methodology best suited and the adequacy of information available to support the impact assessment, and Phase II was the design study in which the environmental and economic assessment methodologies were defined in detail. Phase III was the actual impact assessment, and this report presents the results of that impact assessment.

The impact assessment of SWASS was an application of the Risk Benefit Hazard Assessment (RBHA) methodology (Ketrone, 1979), which was designed for the evaluation of large-scale Federally-sponsored pesticides programs. This methodology has two major components:

- an environmental assessment methodology, Environmental Evaluation of Pesticides, or EEP (Ketrone, 1978), which evaluates the risks, hazards, environmental costs, and environmental-social effects of pesticides programs on wildlife, agriculture, and humans, and
- a methodology to evaluate the economic costs and benefits of pesticides programs.

Accordingly, the impact assessment of the SWASS program is presented in two parts: the environmental assessment of the use of SWASS and the economic analysis of SWASS as a component of the overall screwworm program.

1.1 Background

The screwworm, Cochliomyia hominivorax, is a major pest in the southwestern United States and Mexico. Considerable damage is caused by the larvae of the flies, which feed on live, warm-blooded animals. The major animal hosts for the larvae are cattle, goats, sheep and deer, although there have been a large number of cases where humans have been infested with screwworms.

The female screwworm fly lays her eggs in open wounds, nostrils and navels of new-born mammals. In less than one day the screwworms hatch from the eggs, crawl into the wound and attach themselves inside the wound. The screwworms feed for five to seven days. The odor created by the feeding screwworms makes the wound more attractive to other female screwworm flies for the purpose of depositing their egg masses. After the screwworms finish feeding, they leave the wound and enter the ground to pupate. The pupation may take from seven days to two months depending on temperature, moisture, and soil type. Then, they emerge as adults and are ready to mate within three to five days.

Prior to the 1950's, there was no effective way to control screwworms. The only thing that could be done was to continually clean the wounds that had become infested.

In 1954, sterile male flies were used to eradicate screwworms from Curacao, an island forty miles off the coast of Venezuela. If female screwworm flies mate with a sterile male, their eggs will not hatch. In a sterile male program, native flies are overwhelmed by sterile flies and the number of females that have offspring drops significantly for each generation of flies. Eventually, the fly population collapses. This type of

eradication program was also used to eradicate screwworm flies from Florida in 1959.

The current sterile fly program was instituted in 1962 to set up a barrier in the southwestern United States and Mexico to prevent the spread of screwworm flies into the United States. The ultimate goal is to move the barrier down to the narrowest part of Mexico, the Isthmus of Tehuantepec. This would result in smaller expenditures to maintain the barrier and reduce the risk of future outbreaks of screwworm flies in the United States. It would also eliminate virtually all screwworm cases in Mexico. Although the screwworm has been well controlled with this program, eradication from the southwestern United States and northern Mexico has not been fully achieved and the barrier is still maintained in northern Mexico.

Because of severe outbreaks of screwworms in the United States during 1972 and 1976, other methods of eradication were explored. The program which is the subject of this report is the Screwworm Adult Suppression System (SWASS). The SWASS unit is a bait-toxicant system. It is a pellet containing a chemical bait known as swormlure and the toxicant dichlorvos (DDVP). SWASS has been used in conjunction with the sterile male program to eradicate screwworm flies from Curacao after the island had become reinfested. SWASS is not considered sufficiently effective to eradicate screwworms by itself. It is considered to be most effective when used to reduce the screwworm population to a level that will allow the sterile male program to work more quickly and effectively. It is estimated that SWASS kills 80% of female screwworm flies. This results in a significantly smaller need for sterile flies in the eradication effort.

Executive Order 12114, "Environmental Effects Abroad of Major Federal Actions", requires an environmental assessment of any major Federal action which may significantly affect the envi-

ronment of a foreign nation or "which provides to that nation a product, or physical project producing a principal product or an emission or effluent which is prohibited or strictly regulated by Federal law in the United States because its toxic effects on the environment create a serious public health risk" (E.O. 12114, 2-3(c)(1)). If the SWASS program in Mexico is subject to this Executive Order, an environmental assessment document will have to be prepared for the program to ensure compliance with the Order. At any rate, USDA will conduct an environmental assessment of the program in Mexico. The environmental assessment portion of this study is to be used as the basis for that assessment.

Although this Executive Order does not require an economic assessment of the SWASS program, the economic assessment in this study will enable the Veterinary Services to determine whether or not SWASS is a cost-effective component of the overall screwworm eradication program.

The remainder of this chapter is an introduction to the environmental assessment of the SWASS program. The economic analyses of the SWASS program comprises Chapters 9 and 10 of this report.

1.2 Introduction to the Environmental Assessment of the SWASS Program

The form and content of the environmental assessment document required by E.O. 12114 are not specified precisely, but the assessment must be a "concise review of the environmental issues involved, including environmental assessments, summary environmental analyses or other appropriate documents" (E.O. 12114, 2-4(a)(iii)).

The methodology for the environmental assessment in this study is based on the Environmental Evaluation of Pesticides (EEP) methodology. This is an accepted assessment methodology

and is considered by the Office of Environmental Quality, USDA, to be "adequate for an environmental assessment of the program" and to "meet the needs of Executive Order 12114" (Flamm, 1980).

Although the initial purpose of this study was to conduct an impact assessment of SWASS in the southwestern United States, the document required by E.O. 12114 is an environmental assessment in Mexico. Hence, the approach taken in this study has been to tailor the analyses for easy application to the SWASS program in Mexico. To this end, it was decided to evaluate the use of SWASS in areas of the Southwest which are representative of areas in Mexico where it might first be used.

The results of the environmental assessment are presented in the following format:

- description of the representative regions and definition of the SWASS program parameters - Chapter 2,
- environmental fate and behavior of the SWASS chemicals - Chapter 3,
- assessment of the risk of SWASS to aquatic organisms; terrestrial organisms, including non-target insects, livestock, and wildlife; and humans - Chapters 4, 5, and 6, respectively,
- assessment of research and resource program conflicts and other environmental-social effects - Chapter 7, and
- conclusions - Chapter 8.

CHAPTER 2

PROGRAM DEFINITION

2.0 Introduction

The procedures and results from this study are to be the foundation upon which future assessments of environmental impact in Mexico will be based. With this in mind, the environmental assessment has been focused on regions in the southwestern United States which are representative of areas where SWASS will be used in Mexico. It is anticipated that the use pattern for SWASS in Mexico will be similar to that in the Southwest.

SWASS is employed in response to a significant number of reported screwworm cases or a significant number of wild screw-worm flies caught in traps. Thus, it is impossible to know in advance when or where SWASS might be used. For this reason, it was assumed that SWASS might be applied anywhere in any of the representative regions.

The first portion of this chapter is a description of the representative regions in the southwestern United States. Following this is a discussion of the formulation and application procedures for SWASS.

2.1 Description of the Representative Regions

The United States Forest Service has divided the United States into a set of ecological regions, called ecoregions, based upon differences in land form, climate, soils, flora and fauna (Bailey, 1978). These ecoregions coincide to some extent with the land resource regions defined by the Soil Conservation Service (Austin, 1965), which are characterized by land use, water resources, climate, and soils. We have chosen three ecoregions in the Southwest which also continue well into Mexico:

- Mexican Highlands Shrub-Steppe Province,
- Chihuahuan Desert Province, and
- Prairie Brushland Province.

These regions correspond to the Southeastern Arizona Basin and Range; Southern Desertic Basins, Plains, and Mountains; and Rio Grande Plain Regions, respectively, in the Austin (1965) classification. The boundaries of the ecoregions, which are called "study regions" hereafter, are shown in Figure 2-1. In the following descriptions of the study regions, Land Surface Form, Climate, Vegetation, Soils, and Fauna are taken verbatim from Bailey (1978), and Land Use and Water are taken verbatim from Austin (1965).

2.1.1 Mexican Highlands Shrub-Steppe Province (Ecoregion 1)

Land-surface form. The province covers the grassy plains and the mountains included in them between the American Desert on the west and the Chihuahuan Desert on the east. The plains range in elevation from about 4,000 ft. (1,200 m.) to more than 7,000 ft. (2,100 m.). Above them rise many isolated hills and mountains, some of which reach elevations higher than 9,000 ft. (2,700 m.).

Climate. The climate is semiarid. Most of the precipitation comes in convectional storms during the summer months; rain falls occasionally in winter. The most arid season is late spring and early summer. Because of the high elevation, mean temperatures are moderate, but the summer days are hot. The average annual temperature range is from 55° to 70°F (13° to 21°C). Periods of extremely cold weather may occur in winter.

Vegetation. Four life belts are distinct in this province. The lowest is the desert belt, which extends from the American Desert upward along the San Pedro Wash for a number of miles, north of the Santa Catalina Mountains. Characteristic plants in this belt are the giant cactus or saguaro, paloverde,

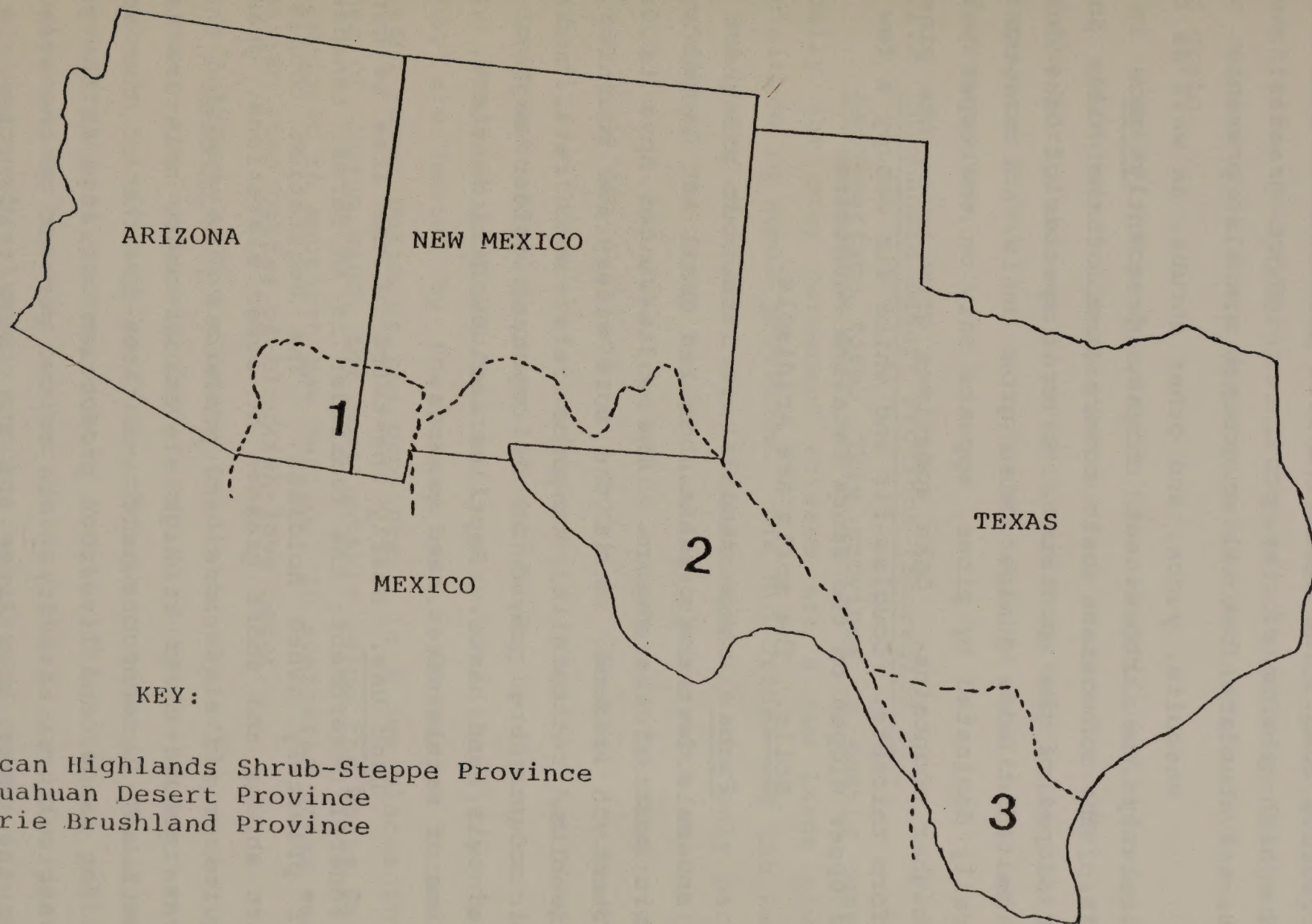


FIGURE 2-1

STUDY AREAS - ECOREGIONS

and creosote bush. The extensive arid grassland belt covers most of the high plains of the province. Short grasses, such as grama, are abundant, but taller grasses are also present.

Mesquite, yucca, and other shrubs, as well as cacti, particularly the arborescent choyas, frequently grow in open stands. The submontane belt covers most of the hills and the lower slopes of the mountains. Several species of oaks dominate this belt but some juniper also grow in it. A montane belt, generally dominated by pines, appears only on the upper parts of the higher mountains. Oaks sometimes grow among the pines and may form thickets. Douglas-fir and white fir occupy a few sheltered upper slopes on the Santa Catalina Mountains.

Soils. The soils are Aridisols.

Fauna. Large mammals are rare, but pronghorn antelope and mule deer are present. Scaled quail and Gambel's quail inhabit most of the region. The white-winged dove is locally important in Arizona, as is the more widespread mourning dove. Jackrabbits, cottontails, kangaroo rats, wood rats, and other small rodents are preyed on by coyotes, golden eagles, great horned owls, and hawks. Reptiles include Gila monsters, various species of rattlesnakes, and lizards.

Land Use. Nearly one-third of the area is owned by the Federal Government; the remainder is in farms, ranches, and other privately owned holdings. The vegetation consists of desert shrubs and short grasses at lower elevations, grass and mesquite at mid elevations, and ponderosa pine woodland that has a grass ground cover at high elevations where moisture is more plentiful. Between one-half and three-fourths of the area is used for range, and livestock production on range is the principal agricultural activity. One or two percent of the area, land along the upper Gila River and its large tributaries, is irrigated. Cotton and alfalfa are the main crops, but specialty

crops are important locally. Where water is of poor quality and less certain in amount, grain and forage to supplement range feed are the main crops. About 1 percent of the land is dryfarmed to hay and grain.

Water. The upper Gila River and its tributaries are the only year-round sources of surface water for irrigation. Much of the irrigation water is obtained from deep wells, but the declining water table and a high salt content limit the usefulness of this source.

2.1.2 Chihuahuan Desert Province (Ecoregion 2)

Land-surface form. This province is mostly desert. Practically the only permanent streams are a few large rivers that originate in humid provinces. The Rio Grande and the Pecos Rivers and a few of their larger tributaries are the only perennial streams. The area has undulating plains with elevations near 4,000 ft. (1,200 m.), from which somewhat isolated mountains rise 2,000 to 5,000 ft. (600 to 1,500 m.). Washes, dry most of the year, fill with water following a rain. Basins that have no outlet drain into shallow playa lakes that dry up during rainless periods. Small whirlwinds constantly play over these dry playas when they are heated by the summer sun. Extensive dunes of silica sand cover parts of the province. In a few places there are dunes of gypsum sand, the most notable being the White Sands near Alamogordo in southern New Mexico. In scattered areas small beds and isolated buttes of blackish lava occur.

Climate. The climate is distinctly arid; spring and early summer are extremely dry. During July the summer rains usually begin, and they continue through October. The summer rains are torrential storms, mostly local. The northern part of the province also receives winter rains; these are more gentle and more widespread. Average annual temperature ranges from 50° to 65°F (10° to 18°C). Summers are long and hot. Winters are

short but may include brief periods when temperatures fall below freezing.

Vegetation. The characteristic vegetation of the Chihuahuan Desert is a number of shrubs, most of them thorny. These shrubs frequently grow in open stands, but sometimes form low closed thickets. Short grass grows in association with the shrubs in many places. On deep soils, mesquite is often the dominant plant. A few cottonwoods and other trees grow beside the widely separated rivers. Creosote bush covers great areas in its characteristic open stand and is especially common on gravel fans. On rocky slopes the ocotillo is conspicuous; on the slopes leading down to the Rio Grande the ceniza shrub dominates. Juniper and pinyons, which are limited to rocky outcrops, are prominent around the Stockton Plateau in western Texas.

Some isolated mountains in the Chihuahuan Province rise high enough to carry a belt of oak and juniper woodland. On a few of the highest mountains pines grow among the oaks, but locally they sometimes grow in nearly pure stands.

Soils. In the western and northern portions, the soils are primarily Aridisols but both Aridisols and Entisols are present in the south.

Fauna. Pronghorn antelope and mule deer are the most widely distributed large game animals. The common white-tailed deer is in Texas. The collared peccary or javelina is common in the southern part of the region. Scaled quail and Gambel's quail are present in most of the area, and the bobwhite reaches the eastern portion. The black-tailed jackrabbit, desert cottontail, kangaroo rat, wood rat, and numerous smaller rodents compete with domestic and wild herbivores for available forage and are preyed upon by the coyote, bobcat, golden eagle, great horned owl, red-tailed hawk, and ferruginous hawk.

Land use. About one-third of the land is owned by the Federal Government; most of the remainder is in farms, ranches, or other private holdings. The federally owned land is concentrated in New Mexico. Two-thirds or more of the total area is in range. Short grasses and desert shrubs cover much of the area, but there are open pinyon-juniper woodlands at high elevations. All this range has a low carrying capacity. Less than 1 percent, consisting mainly of narrow discontinuous strips along the Rio Grande and Pecos Rivers, is irrigated. Other small areas are irrigated from wells. Cotton, cantaloupes, and vegetables are the principal crops; grain sorghum, alfalfa, and other feed and forage crops are grown also.

Water. Surface water and rainfall are scarce throughout the area, which imposes severe restrictions on its use for range. The Rio Grande and Pecos Rivers and a few of their larger tributaries are the only perennial streams. Ground water in deep valley fill provides water for domestic use and livestock and locally for some irrigation.

2.1.3 Prairie Brushland Province (Ecoregion 3)

Land-surface form. This province is a region of rolling plains and plateaus occasionally dissected by canyons at the western end of the Gulf Coastal Plain and the southern end of the Great Plains. Elevations range from sea level to 3,600 ft. (1,100 m.) on the Edwards Plateau. A mesa and butte landscape is characteristic of certain parts.

Climate. The summers are long and hot and the winters are short and mild. Annual temperatures average 60° to 70°F (15° to 21°C). The frost-free season ranges from about 250 to considerably more than 300 days. Precipitation, which falls mostly during the growing season, ranges from 20 to 30 in. (500 to 750 mm.). Annual evaporation is 71 to 79 in. (1,800-2,000 mm.). From May to October, potential evaporation is about twice the precipitation.

Vegetation. This province is characterized by arid grasslands in which shrubs and low trees grow singly or in bunches. On the plains in northwestern Texas, xerophytic grasses (bluestem, three-awn, buffalograss, grama) are the characteristic vegetation. However, in much of this area mesquite grows in open stands among the grasses. On the Edwards Plateau, oak and juniper are often mixed with the grass and mesquite, and on steep rocky slopes these trees may form closed stands. They rarely grow higher than 20 ft. (6.1 m.). Over much of the Plateau the characteristic vegetation is grass; trees and shrubs are present only in very open stands.

Soils. Soils in this region are varied, but the different orders are well correlated with the different plant communities. The mesquite-live oak savanna, for example, is the only Entisol area within the region. Soils of the mesquite-buffalograss and the juniper-oak savanna are almost entirely Mollisols; an island of Alfisols within the sea corresponds with the boundaries of the mesquite-oak savanna. In the mesquite-acacia savanna, Mollisols, Alfisols, and Vertisols occur.

Fauna. The northern limit of distribution of several mammals coincides generally with the northern boundary of this province. The Mexican ground squirrel and gray fox live here and to the south, but not to the north. White-tailed deer and wild turkey are abundant and armadillo are present. The fox squirrel is hunted in wooded areas along streams. Chief furbearers are the ringtail and the raccoon.

The golden-cheeked warbler is a threatened species. Mourning dove, scaled quail, and bobwhite are common game birds and several species of hawks and owls are present.

Land use. Nearly all the land is in farms and ranches. About four-fifths of it is in range of native shrubs and grasses grazed by beef cattle. Nearly 10 percent of the

area, mainly along the Rio Grande and Nueces Rivers, is irrigated. Cotton, seed corn, sweet corn, citrus fruit, melons, and many kinds of vegetables are grown. About the same amount of land in the north and the east is used for crops without irrigation or with only supplemental irrigation. Cotton, grain, sorghum, flax, and hay are the principal crops.

Water. The high summer temperatures reduce the effectiveness of the relatively low to moderate rainfall. The Rio Grande and Nueces Rivers provide water for irrigation, but the smaller streams have a small and intermittent flow and are little used for irrigation. Ground water is abundant throughout the area, and wells provide water for livestock, domestic use, and some irrigation.

2.2 Characteristics of the SWASS Program

Formulation. SWASS is applied as pellets containing a toxicant, a chemical attractant, and bait materials. Table 2-1 lists the pellet components.

Dichlorvos (DDVP, Vapona), or 2,2-dichlorovinyl dimethyl phosphate, is an organophosphate insecticide with high volatility and rapid knockdown effects. This toxicant is impregnated in corn cob grits for incorporation into the SWASS pellets. The chemical attractants are known collectively as swormlure-2 and are bound in the KSL Wax. The blood and sugar are the actual bait materials upon which the flies feed. The total weight of a pellet is about 3 grams.

Application of baits. SWASS is used in conjunction with the release of sterile male flies when it is felt that the release of sterile males alone may not be able to prevent an outbreak. It is a reactive technique, used in response to a known screwworm infestation or outbreak. The criteria for the use of SWASS are as follows:

TABLE 2-1
COMPOSITION OF SWASS PELLETS

<u>Compound</u>	<u>Percent</u>	<u>Use</u>
dichlorvos	2.0	toxicant
acetic acid (glacial)	3.2	attractant
butyric acid	3.0	attractant
valeric acid	2.9	attractant
isobutanol	2.5	attractant
sec-butanol	2.5	attractant
benzoic acid	0.6	attractant
phenol	2.8	attractant
p-cresol	2.7	attractant
indole	0.6	attractant
methyl disulfide	2.8	attractant
dried blood	30.5	bait material
sugar	30.5	bait material
corn cob grits	7.5	bait material
KSL Wax	5.9	bait material

- five or more reported screwworm cases for two consecutive weeks, or
- 0.5 native screwworm flies per wind oriented swormlure baited trap.

Treatment areas range in size from 150 to 1000 square miles, the average being 400 square miles. The SWASS pellets are applied by airplanes at a rate of one pound of pellets per square mile. This is equivalent to 150 pellets per square mile or one pellet per 4.3 acres. The normal timing of applications is two treatments per week for two weeks, although some treatments have taken as long as seven weeks.

In order to reduce the exposure of aquatic organisms, humans, and certain endangered species to SWASS, certain constraints on the aerial application of pellets are observed during a treatment program. These are as follows:

- SWASS is not applied within $\frac{1}{2}$ mile of any streams, rivers, lakes, or other waters,
- SWASS is applied only on rangeland in sparsely populated areas, and
- SWASS is not applied within certain designated areas inhabited by one or more endangered species of wildlife.

Restricted areas include the following:

- A rectangular area in New Mexico bounded by the following meridians: east $107^{\circ} 45'$, north $33^{\circ} 26'$, west $108^{\circ} 50'$, south $32^{\circ} 55'$. This area is in the Gila and Apache National Forests and is to the north of Ecoregion 1.
- Areas in New Mexico within a twenty mile radius of Blue Springs, the village of Dexter, Bottomless Lakes State Park and Bitter Lake National Wildlife Refuge. These restricted areas are in the Pecos watershed of Ecoregion 2 and together with the first area were established by the Veterinary Services in cooperation with the U. S. Fish and Wildlife Service to protect endangered species of fish.

- Big Bend National Park, Texas, in Eco-region 2.

These restricted areas and the major rivers in the study regions are shown in Figure 2-2.

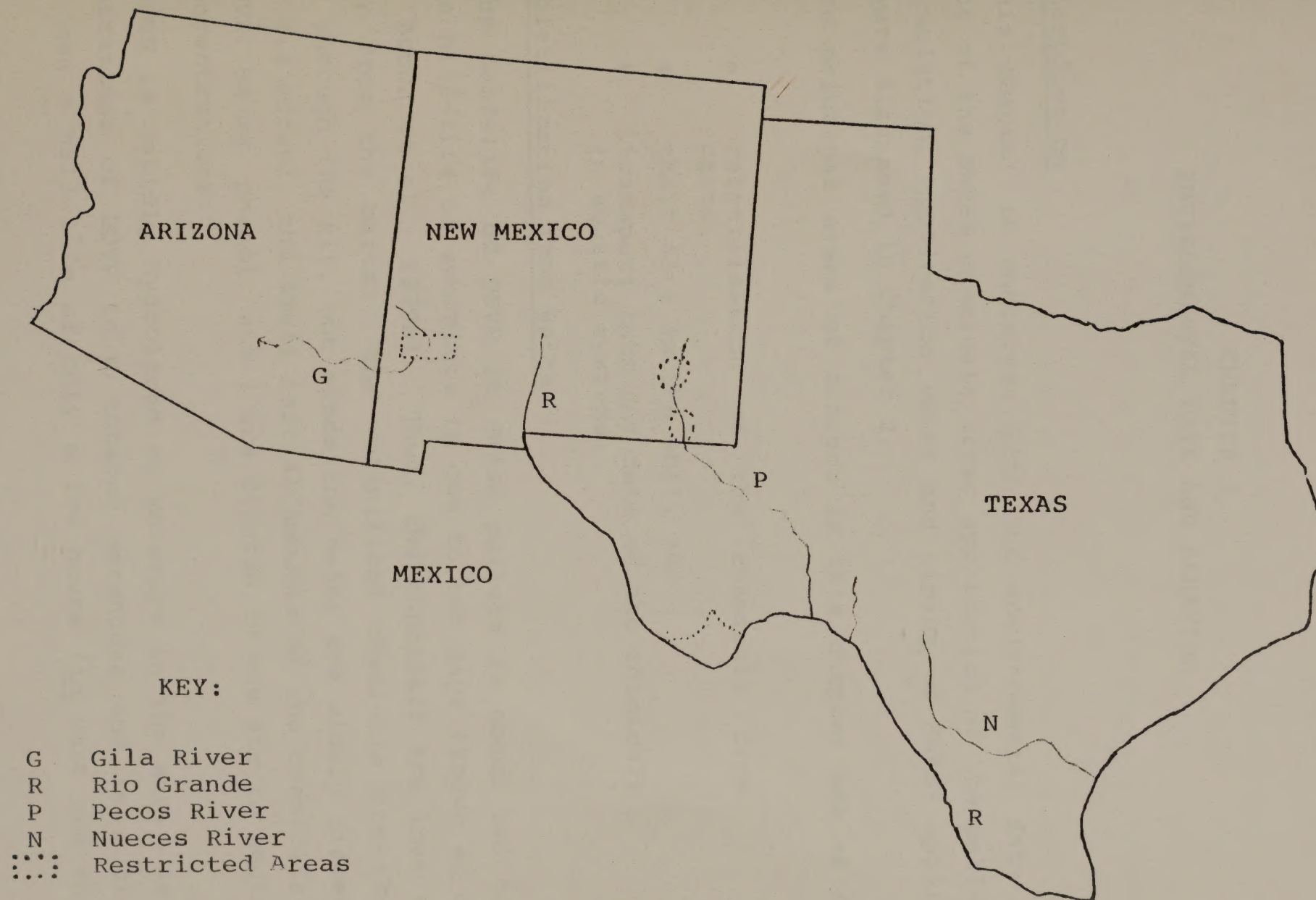


FIGURE 2-2

MAJOR RIVERS AND RESTRICTED
AREAS IN THE STUDY REGIONS

CHAPTER 3

ENVIRONMENTAL FATE AND BEHAVIOR

3.0 Introduction

This chapter is concerned with the environmental fate and behavior of the SWASS chemicals after application of the pellets. The formulation, application rates and timing of SWASS applications were discussed in Chapter 2.

The principal areas of concern in this chapter are as follows:

- volatilization of the chemicals from baits,
- their fate in the soil, and
- transport into and fate of the chemicals in aquatic systems.

3.1 Volatilization from Baits

The half-life of DDVP in SWASS pellets is about two days, and the half-life of swormlure is one to two days (Brown et al., 1979a, Brown et al., 1979b). Thus, the chemicals are lost very rapidly from the baits. The volatilized chemicals are transported through the air, but since the baits are widely dispersed (1 per 4.3 acres), the small initial amounts of the chemicals (60 mg. DDVP, 84 mg. phenol, etc.) are diluted in the air to negligible concentrations.

DDVP is rapidly hydrolyzed by moisture in the air. Aerial concentrations of DDVP in a tobacco warehouse and in a closed office had a half life of only a few hours (in Hurt and Pharm, 1964).

3.2 Fate in the Soil

Garcia Acosta et al. (1980) found that DDVP diffuses into the soil around a SWASS pellet to a radius of about 50 cm, and concentrations of up to 17.4 ppm were found in the soil. The chemicals in a SWASS pellet might also be carried into the soil during a rainfall.

However, the chemicals in SWASS are not expected to accumulate in the soil. DDVP is hydrolyzed by soil moisture and degraded by several varieties of microorganisms. Lameroux and Newland (1978) and Getz and Rosefield (1968) observed a half-life in soil for DDVP of less than a week. The principal hydrolysis products are dimethyl phosphate and dichloroacetaldehyde; the former is practically non-toxic, and the latter rapidly decomposes and evaporates (Melnikov, 1971).

Phenol and p-cresol are easily degraded by many widely-distributed species of bacteria and fungi (Gagley, 1967). Butyric, valeric and benzoic acids occur naturally in soils and are metabolized by microorganisms (Stevenson, 1967). The other chemicals in swormlure are naturally occurring compounds with simple structures and are probably easily degraded by microorganisms.

3.3 Transport and Fate in Aquatic Systems

Precautions are taken to prevent the chemicals in SWASS from entering aquatic systems. SWASS pellets are not to be dropped within $\frac{1}{2}$ mile of any stream, lake, estuary, or other body of water. Airplanes are equipped with cutoffs so that pilots can cease application of the pellets within the specified distance of streams, lakes, and relatively visible ponds. However, pilots cannot normally avoid very small ponds and "cattle tanks," which are often only $\frac{1}{4}$ acre in size.

The two principal mechanisms for transport of SWASS chemicals into aquatic systems are surface runoff and inadvertent application of pellets onto water.

3.3.1 Runoff

The ecoregions in which SWASS is applied are relatively dry, and the precipitation is fairly seasonal (Table 3-1). The wettest months occur in the summer and early fall, when SWASS might be applied. However, for the following seasons, the quantities of SWASS chemicals which might be transported into aquatic systems by runoff appear negligible.

The annual runoff in these areas is extremely small (Table 3-1), which indicates that the vast majority of the rainfall is absorbed into the ground rather than carried into streams.

TABLE 3-1
RAINFALL DATA FOR ECOREGIONS

<u>Ecoregion</u>	<u>Average Annual Rainfall (in.)</u>	<u>Wettest Months</u>	<u>Average Annual Runoff (in.)</u>
1	8-20	Jul, Aug	<.05
2	8-20	Jun-Sep	<.02
3	20-30	May, Jun Aug-Oct	<.05

There are only 60 mg. of DDVP in a SWASS pellet and comparable quantities of the other chemicals. Moreover, the pellets are applied at an extreme dispersal, only one pellet per 4.3 acres.

The chemicals from a SWASS pellet would have to be carried at least $\frac{1}{2}$ mile in order to reach a stream, and extreme dilution would occur because of mixing with the runoff from adjoining areas. Still further dilution would occur upon entering a stream.

Moreover, much if not most of the DDVP and swormlure in a SWASS pellet would volatilize and dissipate before a rainfall event.

Therefore, the transport of SWASS chemicals by runoff into streams is extremely unlikely, and concentrations of DDVP and swormlure in streams, lakes, or estuaries would be negligible.

3.3.2 Inadvertent Application to Ponds

Inadvertent application of SWASS pellets to small ponds is the most likely route of transport for DDVP and swormlure into aquatic systems.

The probability (p) that a pellet will land in a pond depends on the size of the pond. Assuming a uniform distribution of pellets of 1 per 4.3 acres, the probability that a pond will receive a pellet during an application is 0.23 times the size of the pond in acres. For a $\frac{1}{4}$ acre cattle tank, p is .058 (about one chance in 17). If it is assumed that a SWASS treatment requires four applications, the probability that the pond will receive at least one pellet during treatment is .21, or about one chance in 5.

Most of the SWASS chemicals are somewhat soluble in water (Table 3-2), and they will diffuse throughout the water column.

The behavior of SWASS chemicals in water depends upon the pH, temperature, and biological properties of the water. DDVP is hydrolyzed in solution relatively rapidly in alkaline and

neutral solutions and relatively slowly in acid solutions. The rate of hydrolysis increases two to five times for every 10°C increase in temperature (Drevenkar et al., 1976). Figure 3-1 shows hydrolysis rates determined for DDVP in the laboratory. DDVP is also degraded by aquatic microorganisms.

There is little information available concerning the fate of DDVP in natural waters. Half-lives for small concentrations of DDVP in river water have been estimated to be one week to over two weeks in Yugoslavian rivers of unspecified temperature and pH (Drevenkar et al., 1975) and five to six days in Japanese water at 28°C and unspecified pH (Yasuno et al., 1965). However, these rivers drain humid areas where the natural vegetation is forests. River water in western Pennsylvania, with comparable natural vegetation and soils, has a pH generally between 6.5 and 7.5, so that a half of a week or more in such waters is to be expected.

However, the pH of surface waters in Arizona, New Mexico and west Texas is around 8.0, while average summer temperatures in the rivers are 20°C or above (USGS, 1977a; USGS, 1977b). Surface waters in south Texas are normally alkaline, with a pH greater than 8.0 (Brown, personal communication). This suggests that DDVP would hydrolyze relatively rapidly in these surface waters -- the half-life probably being a day or two.

Phenol and p-cresol are easily degraded by aquatic microorganisms and should not accumulate in water. The other swormlure chemicals are naturally occurring compounds of simple structure and should disappear very quickly.

The concentration of a chemical in water at a given time is given by the equation $C_t = C_0 \exp (-0.693 t/H)$, where C_t is the concentration at a given time, C_0 is the initial concentration, H is the half-life, and t is the length of time. For example, assume that a pellet lands in a $\frac{1}{4}$ acre pond with an

TABLE 3-2
DENSITY AND SOLUBILITY OF SWASS CHEMICALS

<u>CHEMICAL</u>	<u>DENSITY (G/CM³)</u>	<u>SOLUBILITY IN WATER</u>
DDVP	1.44	slightly sol.
acetic acid	1.05	infinite
butyric acid	0.96	infinite
valeric acid	0.94	soluble
isobutanol	0.81	very sol.
sec-butanol	0.81	very sol.
benzoic acid	1.27	slightly sol.
phenol	1.07	slightly sol.
p-cresol	1.02	slightly sol.
indole	1.22	sol. (hot water)
dimethyl disulfide	1.06	insoluble

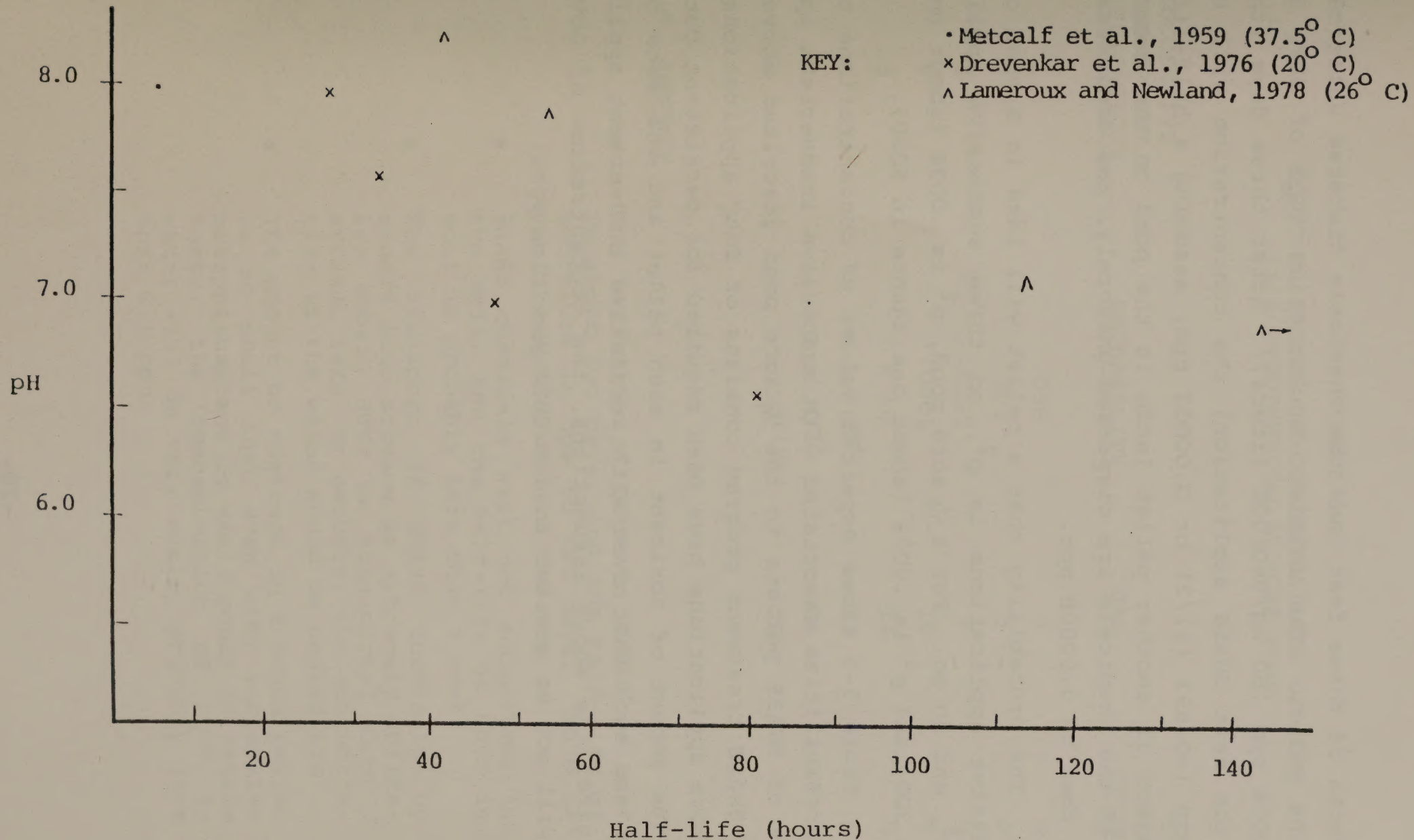


FIGURE 3-1
HALF-LIFE OF DDVP IN
WATER (LABORATORY)

average depth of three feet, and the chemicals disperse uniformly through the water. The initial concentration (C_0) of DDVP is then 0.00006 ppm (60 mg/940,000 liters). After three days (the time of the next SWASS application) the concentration will be $0.00006 \exp(-0.693 (3)/2)$ or 0.00002 ppm, assuming a half-life of two days. If another pellet lands in the pond on the fourth day, and if the chemicals are dispersed uniformly, the concentration will then be 0.00008 ppm.

The probability that a pellet will land in a pond on two successive applications is p^2 , on three successive applications p^3 , and so on. For a $\frac{1}{4}$ acre pond, p^2 is .0034 (about one chance in 300) and p^3 is .0002 (about one chance in 5000).

Table 3-3 shows expected values of concentrations of DDVP and probabilities associated with successive inadvertent applications of SWASS pellets to the $\frac{1}{4}$ acre pond described above. A typical SWASS treatment program consists of four applications, although more applications have been required for persistent outbreaks. The amount of toxicant in each pellet and the rate of hydrolysis are such that even with successive inadvertent applications, given the above assumptions, the concentration of DDVP in water will not be greater than 0.0001 ppm (0.1 ppb).

TABLE 3-3
EXPECTED VALUES OF CONCENTRATIONS OF DDVP
IN A HYPOTHETICAL $\frac{1}{4}$ ACRE POND

<u>SUCCESSIVE INADVERTENT APPLICATIONS</u>	<u>PROBABILITY</u>	<u>DAY</u>	<u>EXPECTED CONCENTRATION OF DDVP (PPM)</u>
1	.058	0	0.000064
2	.003	3	0.000083
3	.0002	7	0.000085
4	.0001	10	0.000094
5	7×10^{-7}	14	0.000088
6	4×10^{-8}	17	0.000095
7	2×10^{-9}	21	0.000088
8	1×10^{-10}	24	0.000095

3.4 Summary

- The half-life of DDVP in SWASS pellets is about two days, and the half-life of swormlure is one to two days. DDVP is rapidly hydrolized in the air.
- SWASS chemicals will not accumulate in the soil, and the half-life of DDVP in soil is probably less than a week.
- The transport of SWASS chemicals by runoff into streams is extremely unlikely; should DDVP be transported into a stream, lake, or estuary, the concentration in the water would be negligible.
- The amount of toxicant in a SWASS pellet is so small that even with successive misapplications to small ponds or cattle tanks, the concentration of DDVP in water will be very small, probably less than 0.1 ppb.

CHAPTER 4

EFFECTS ON AQUATIC ORGANISMS

4.0 Introduction

This chapter is the first of three which are concerned with evaluating the risk of SWASS to non-target organisms. The evaluation of risk has three principal components:

- determination of hazard, which is the intrinsic toxicity of a chemical to an organism,
- determination of exposure of organisms to the chemicals, including the probability of exposure and the level of uptake, and
- determination of risk, which is the probability and magnitude of effects on organisms given the assumed use pattern of SWASS.

4.1 Hazard of SWASS Chemicals to Aquatic Organisms

The most convenient indicator of hazard for most chemicals is acute toxicity, the single dosage necessary to produce death (Tucker and Crabtree, 1970). For aquatic organisms, this is usually expressed as an LC_{50} (median lethal concentration) which is the concentration of the substance in water which kills 50 percent of the test organisms exposed. Also of concern is chronic toxicity, which is determined by long-term exposure of organisms to sublethal dosages of the substance.

The principal chemical of concern in the SWASS pellet is the toxicant, DDVP. However, several of the swarmlure components, particularly phenol and p-cresol, are also rather toxic. The toxicity of both DDVP and swarmlure will be considered in the hazard analyses.

4.1.1 Hazard of DDVP

Acute Toxicity. The LC_{50} s for various fishes and arthropods have been drawn from several studies cited in toxicological literature and are compiled in Table 4-1. It should be noted that the techniques for determining concentration, exposure methods, exposure lengths, and grade of DDVP vary with the sources of toxicity information. The table contains the best information available for making approximate calculations of acute toxicosis found in aquatic environments.

No acute toxicity data were available for reptiles or amphibians. However, the toxicity of two other organophosphate insecticides (malathion and parathion) to amphibians is comparable to their toxicity to fish.

Chronic Toxicity. In a study by Rath and Misra (1979), the freshwater fish Tilapia mossambica was exposed to short-term (15 days), sub-lethal concentrations (0.5-1.0 ppm) of DDVP. The exposed Tilapia showed irreversible damage to the respiratory system (after being transferred to freshwater the respiratory rates did not return to pre-exposure levels). Rath compared these results with those for other measurable pollutants and concluded any measurable pollutant could cause a similar depression in oxygen uptake. These experiments also indicated that DDVP is degraded in fish.

4.1.2 Hazard of Swormlure

From the little information that is known, the swormlure chemicals appear to be much less toxic to aquatic organisms than DDVP. Toxicity data were located for phenol and p-cresol (in Buikema et al., 1979; Pimentel, 1971) and benzoic acid (Pimentel, 1971).

TABLE 4-1

ACUTE TOXICITY OF DDVP TO AQUATIC ORGANISMS

<u>ORGANISM</u>	<u>EXPOSURE TIME (HR)</u>	<u>LC₅₀ (PPM)</u>	<u>SOURCE</u>
PHYTOPLANKTON (freshwater)	168	>5	Konar (1969)
ZOOPLANKTON			
seven freshwater species	168	>0.2	Konar (1969)
water flea (<u>Daphnia pulex</u>)	24	0.00007	FWPCA (1968)
ARTHROPODS			
amphipods (2 sp.)	24	0.001, 0.002	FWPCA (1968), Sanders (1969)
sand shrimp	24	0.018	Eisler (1969)
grass shrimp	24	0.390	Eisler (1969)
hermit crab	24	0.150	Eisler (1969)
stone flies (2 sp.)	24	0.01, 0.023	FWPCA (1968), Cope (1965)
water bugs (5 sp.)	168	0.00123 - 0.28	Konar (1969)
water beetles (3 sp.)	168	0.064 - 0.35	Konar (1969)
anisopteran nymphs	168	0.15	Konar (1969)
MOLLUSKS (2 sp.)	96	>25	Eisler (1970b)
FISH			
rainbow trout	24	0.5	Vevai (1974)
bluegill	24, 48	1, 0.7	Vevai (1974), FWPCA (1968)
harlequin fish	24, 48	12, 7.8	Alabaster (1969)
fry, freshwater (5 sp.)	168	0.76 - 11.22	Konar (1969)
fingerlings, freshwater (2 sp.)	168	1.77, 1.82	Konar (1969)
adults, freshwater (13 sp.)	168	2.42 - 22.38	Konar (1969)
adults, estuarine (7 sp.)	96	0.2 - 2.33	Eisler (1970a)

Phenol at 8 ppm inhibits algae growth. Published LC_{50} 's of phenol for aquatic organisms range from 1.5 ppm for daphnids to 4-12 ppm for rainbow trout, 13-24 ppm for bluegill, 17 ppm for channel catfish, and 32 ppm for fathead minnows. Exposure of brown trout, bluegill and goldfish to 5 ppm phenol for 22 hours resulted in no mortality in any of the species. P-cresol appears to be more toxic, having an LC_{50} for fathead minnows of 19 ppm and a subcutaneous LD_{50} for frogs of 150 mg/kg. The subcutaneous LD_{50} for frogs of benzoic acid is 100-200 mg/kg.

Fish exposed to 5-100 ppm phenol concentrated the compound 2 to 3 times at 1 to 3 days exposure (in Buikema et al., 1979). After exposure to clean water, fish lost 75% of the dose in one hour and 85-90% in 3 to 4 hours.

4.2 Exposure of Aquatic Organisms to SWASS Chemicals

As discussed in Section 3.3, the aquatic habitats most likely to be exposed to SWASS chemicals are the small ponds and livestock tanks which cannot normally be avoided by aerial applicators. These ponds are often 100 feet or less across ($\frac{1}{4}$ acre is a typical surface area), and the depth averages around three feet. In southern Arizona, there is normally one cattle tank per square mile or so. Cattle tanks may dry up on occasion; thus fish are not normally found in these small ponds unless they are stocked. However, some ponds will support populations of arthropods and amphibians.

It was demonstrated in Section 3.3 that the probability that a $\frac{1}{4}$ acre pond would receive at least one SWASS pellet during a two-week treatment program is only about .21 (one chance in 5). Even with successive inadvertent applications of SWASS to a pond, the concentration of DDVP in water is not expected to be higher than 0.1 ppb.

The majority of the aquatic species of interest, especially the rare or economically important species, are found in streams, lakes, and estuaries.

There are very few permanent streams in the southern part of Ecoregion 1. However, there are some permanent springs and a few small streams in the headwaters of the Yaqui, Santa Cruz, and San Pedro River drainages. Populations of fish are supported, several species of which are listed as endangered or threatened (see Section 4.5). In the northern part of Ecoregion 1 are some permanent streams in the upper Gila River drainage. The aerial application of SWASS is prohibited in the New Mexico portion of this drainage because of the presence of endangered species of fish.

The only permanent streams in Ecoregion 2 are the Mimbres, Rio Grande, Pecos, and a few short tributaries. The aerial application of SWASS is prohibited in most of the New Mexico portion of the Pecos drainage and in Big Bend National Park on the Rio Grande.

Again, there is very little in the way of natural surface water in most of Ecoregion 3 except for the Nueces (and a few tributaries), the Rio Grande, and a few short coastal streams. On the coast is Laguna Madre, a hypersaline estuary which supports some commercial fisheries. In the lower Rio Grande Valley there is an abundance of surface water in the form of irrigation canals and flood channels.

The aerial application of SWASS is prohibited within $\frac{1}{2}$ mile of lakes, streams, and estuaries. With the exception of the designated areas in New Mexico and Texas and in the lower Rio Grande Valley, there is very little area in Ecoregions 1, 2 or 3 where the use of SWASS is restricted because of considerations for aquatic organisms. Given these restrictions, the concentration of DDVP in these waters will be negligible, certainly less than the 0.1 ppb which might be encountered in livestock tanks.

4.3 Risk to Aquatic Organisms from SWASS

Because DDVP appears to be far more toxic to aquatic organisms than any of the swormlure chemicals, the risk to organisms was determined by comparing potential DDVP residues in water (0.1 ppb in ponds, less than 0.1 ppb in streams, lakes, and estuaries) with the acute and chronic toxicity data for DDVP (Section 4.1).

4.3.1 Phytoplankton

The use of SWASS is expected to have no effect on phytoplankton.

4.3.2 Zooplankton

These organisms are very important as food sources to larger organisms. The tests by Konar (1969) suggest that most zooplankton species would not be affected by SWASS. Water fleas, which are minute aquatic crustaceans, are extremely sensitive to DDVP, and some mortality would be expected should a small pond be exposed to a SWASS pellet. However, because most other zooplankton species appear more tolerant, there would be little effect on the food web in small ponds. Concentrations of DDVP in lakes, streams, and estuaries are expected to be well below the LC_{50} 's of all zooplankton.

4.3.3 Arthropods

With the exception of water fleas, the LC_{50} 's of aquatic arthropods are at least 10 times higher than the potential concentration of DDVP in water. The LC_{50} 's of economically important crustaceans, such as crabs, shrimp and prawns, are two to three orders of magnitude higher than the potential concentration of DDVP in ponds, which overestimates the concentration in streams and estuaries. No effects are expected on non-planktonic aquatic arthropods.

4.3.4 Mollusks

Mollusks are relatively tolerant of DDVP, and no effects are expected on these species.

4.3.5 Fish

The LC_{50} of the most sensitive fish, the rainbow trout, is three to four orders of magnitude higher than the potential concentration of DDVP in ponds. Chronic effects were observed in Tilapia at concentrations of $\frac{1}{4}$ to $\frac{1}{2}$ the LC_{50} , but it is doubtful that concentrations of 0.1 ppb and less would have any chronic effects on fish. Assuming that pellets are not applied within $\frac{1}{2}$ mile of waterways, the use of SWASS is expected to have no effects on fish.

4.3.6 Reptiles and Amphibians

Assuming that the toxicity of DDVP to amphibians is comparable to that of fish, no effects are expected on amphibian species. No toxicity data are available for reptiles, but if the susceptibility to DDVP is likewise comparable to that of fish (there is no information to indicate otherwise), no effects are expected on aquatic reptiles.

4.4 Residues in Aquatic Organisms

DDVP is degraded by fish, although no rates are available. If the compound is hydrolyzed by enzymes, as is the case with mammals, the degradation rate may be extremely rapid (see Section 5). Because of this and because water supporting fisheries will contain negligible concentrations of DDVP, no residues are expected in fish or any other fisheries products.

Fish have been shown to concentrate phenol two to three times (see Section 4.1). However, even with several inadvertent applications of SWASS pellets to a fishpond, the residue of phenol (or p-cresol, by inference) in a fish would still be less than 1 ppb. These residues are transient, because fish (and

certainly other organisms as well) rapidly lose phenol upon exposure to clean water. Residues in fisheries products from streams, lakes and estuaries will be negligible.

4.5 Aquatic Endangered and Threatened Species

The U. S. Department of Interior has the authority under the Endangered Species Act to declare a species or subspecies endangered or threatened. A species is listed as endangered if it is in danger of extinction throughout all or a significant portion of its range, and as threatened if it is likely to become endangered within the foreseeable future. Federal agencies are required by the Act to determine if their actions may affect any of these species.

State governments may also list species or subspecies as endangered or threatened. However, these are species whose survival or recruitment within the boundaries of the state is in jeopardy or likely to become so. Listed species are not necessarily in danger of extinction. For example, a species listed by New Mexico may occur peripherally in that state but may be very common in Mexico.

Several aquatic endangered and threatened species occur within the area of SWASS use, and these are given in Table 4-2. As mentioned in Section 4.2, the aerial application of SWASS is restricted in certain portions of New Mexico (the upper Gila River drainage and most of the Pecos River drainage) because of the presence of endangered fish species. A "(G)" in Table 4-2 indicates that all or most of a species' distribution in New Mexico is in the Gila restricted area, and a "(P)" indicates the same for the Pecos restricted areas. The application of SWASS is also prohibited in Big Bend National Park, and a "(B)" in Table 4-2 indicates that a significant portion of the species' distribution is within the park.

TABLE 4-2
AQUATIC ENDANGERED AND THREATENED SPECIES

Amphibians - National Listing

Common Name	Latin name	Ecoregion	Status
Texas blind salamander	<u>Typhlomolge rathbuni</u>	3	E

Amphibians - State Listing

Common Name	Latin Name	State Listed	Ecoregion	Status
Colorado river toad	<u>Bufo alvarius</u>	NM	1	T
Monarch tiger salamander	<u>Ambystoma tigrinum stebbinsi</u>	AZ	1	E
Tarahumara frog	<u>Rana tarahumarae</u>	AZ	1	T
Blanchard's cricket frog	<u>Acris crepitans blanchardi</u>	NM	2(P)	T
Eastern barking frog	<u>Hyloactophryne augusti latrans</u>	NM	2M(P)	T
Mexican cliff frog	<u>Syrhophus guttilatus</u>	TX	2(B)	T
Black-spotted newt	<u>Notophthalmus m. meridionalis</u>	TX	3	T
Marbled toad	<u>Bufo marinus</u>	TX	3M	T
Mexican burrowing toad	<u>Rhino phrynus dorsalis</u>	TX	3M	T
Mexican tree frog	<u>Smilisca baudini</u>	TX	3M	T
Rio Grande frog	<u>Syrhophus cystignathoides campi</u>	TX	3M	T
Rio Grande siren	<u>Siren intermedia texana</u>	TX	3	T
White-lipped frog	<u>Leptodactylus labialis</u>	TX	3M	T

Fish - National Listing

Common Name	Latin Name	Ecoregion	Status
Gila Topminnow (AZ)	<u>Poeciliopsis occidentalis</u>	1M	E
Gila trout (NM)	<u>Salmo gilae</u>	1(G)	E
Big Bend gambusia	<u>Gambusia gaigei</u>	2(B)	E
Comanche Springs pupfish (TX)	<u>Cyprinodon elegans</u>	2(P)	E
Mecos gambusia (NM, TX)	<u>Gambusia nobilis</u>	2	E

Fish - State Listing

Common Name	Latin Name	State Listed	Ecoregion	Status
Arizona trout	<u>Salmo apache</u>	AZ	1(G)	T
Chihuahuahua chub	<u>Gila nigrescens</u>	NM	1	E
Coach minnow	<u>Tiaroga cobitis</u>	AZ, NM	1(G)	T
Pikedace	<u>Meda fulgida</u>	NM	1(G)	T
Aquatic chub	<u>Gila purpurea</u>	AZ	1	E
Aquatic topminnow	<u>Poeciliopsis occidentalis sonoriensis</u>	AZ	1	E
Gila chub	<u>Gila intermedia</u>	NM	1, 2	E
Mexican stone roller	<u>Canpostoma ornatum pricei</u>	AZ, TX	1, 2(B)	E, T
Roundtail chub	<u>Gila robusta grahami</u>	NM	1, 2(G)	T
Bigscale logperch	<u>Percina macrolepidia</u>	NM	2(G)	T
Bluntnose shiner	<u>Notropis simus</u>	NM	2	E
Chihuahuahua shiner	<u>Notropis chihuahuahua</u>	TX	2(B)	T
Comchos pupfish	<u>Cyprinodon eximius</u>	TX	2	T
Devils River minnow	<u>Dionda diaboli</u>	TX	2	T
Gray redhorse	<u>Moxostoma congestum</u>	NM	2(P)	E
Greenthroat darter	<u>Etheostoma lepidum</u>	NM	2(P)	T
Leon Springs pupfish	<u>Cyprinodon bovinus</u>	TX	2	E
Mexican tetra	<u>Astyanax mexicanus</u>	NM	2(P)	T
Prosperine shiner	<u>Notropis proserpinus</u>	TX	2	T
Silverband shiner	<u>Notropis cf. shumardi</u>	NM	2(P)	E
Silvery minnow	<u>Hybognathus nuchalis</u>	NM	2(P)	T
White Sands pupfish	<u>Cyprinodon tularosa</u>	NM	2	T
Spotted gambusia	<u>Gambusia senilis</u>	TX	2, 3	T
Blue sucker	<u>Cycleptus elongatus</u>	NM, TX	2, 3	E, T
Rio Grande chub	<u>Gila pandora</u>	TX	2, 3	T
Rio Grande darter	<u>Etheostoma grahami</u>	TX	2, 3	T

Reptiles - National Listing

Common Name	Latin Name	Ecoregion	Status
American alligator (TX)	<u>Alligator mississippiensis</u>	3M	T
Atlantic green turtle (or Green sea turtle) (TX)	<u>Chelonia mydas</u>	3M	E
Atlantic ridley turtle (or Kemp's Ridley sea turtle) (TX)	<u>Lepidochelys kempii</u>	3M	E
Hawksbill sea turtle	<u>Eretmochelys imbricata</u>	3M	E

TABLE 4-2 (Continued)
AQUATIC ENDANGERED AND THREATENED SPECIES

Reptiles - State Listing

<u>Common Name</u>	<u>Latin Name</u>	<u>State Listed</u>	<u>Ecoregion</u>	<u>Status</u>
Big Bend mud turtle	<u>Kinostemon hirtipes murrayi</u>	TX	2(B)	T
Blotched plain-bellied water snake	<u>Natrix erythrogaster transversa</u>	NM	2(P)	T
Texas slider turtle	<u>Chrysemys concinna texana</u>	NM	2(P)	T
Atlantic loggerhead turtle	<u>Caretta c. caretta</u>	TX	3M	T
Leatherback turtle	<u>Dermochelys coriacea</u>	TX	3M	E

Key: () = Federally listed species also on state lists

AZ = Arizona

NM = New Mexico

TX = Texas

M = extending into Mexico

Ecoregions 1, 2, 3 - see Figure 1

(G, P, B) see Section 4.5 in text

E = Endangered: any species in danger of extinction throughout all or a significant portion of its range.

T = Threatened: any species likely to become an endangered species within the foreseeable future throughout all a significant portion of its range.

4.5.1 Federally Listed Aquatic Endangered and Threatened Species

Five species of fish and four species of aquatic reptiles listed by USDI occur in the study area. Of the fish species, the Gila trout, Pecos gambusia, and Big Bend gambusia occur in areas where the aerial application of SWASS is prohibited. All four reptiles are found in areas not likely to be exposed to SWASS, the alligator in wet areas to the extreme north of Ecoregion 3, and the three sea turtles in Laguna Madre and on Padre Island.

The remaining species are the Gila topminnow and the Comanche Springs pupfish. The former occurs in springs and headwater streams in southern Arizona, while the pupfish is found in Comanche Springs, north of Fort Stockton in Pecos County, Texas.

Given the restriction that pellets will not be applied within $\frac{1}{2}$ mile of streams (including springs and headwaters), lakes, and estuaries, the use of SWASS will have no effect on Federally listed aquatic endangered and threatened species.

4.5.2 State Listed Aquatic Endangered and Threatened Species

Several species of fish and reptiles listed as endangered or threatened by Arizona, New Mexico, or Texas occur within the study area. Many of these species will not be exposed to SWASS because either a significant portion of their range is within restricted areas (G, P, or B) or because they are marine species (sea turtles). In any event, given the restrictions concerning the application of pellets near waterways, the use of SWASS will have no effect on state-listed aquatic endangered or threatened species.

4.6 Summary

- Water fleas, which are minute crustacean zooplankton, are extremely sensitive to DDVP, and some mortality might be expected with inadvertent application of a pellet to a small pond or cattle tank. However, because most zooplankton are more tolerant, no effects are expected on aquatic food webs. Concentrations of DDVP in lakes, streams, and estuaries are expected to be below the LC₅₀'s of all zooplankton.
- When applied in accordance with its restrictions, SWASS will have no effects on phytoplankton, aquatic arthropods, mollusks, or aquatic vertebrates.
- No residues of DDVP are expected in fish or any other fisheries products. Even with several inadvertent applications of SWASS pellets to a fishpond, residues of the most toxic swormlure chemicals in fish (phenol and p-cresol) would still be less than 1 ppb. Residues in fisheries products from streams, lakes, or estuaries would be negligible. Swormlure residues in aquatic organisms are transient.
- When applied in accordance with its restrictions, SWASS will have no effects on aquatic endangered or threatened species.

CHAPTER 5

EFFECTS ON TERRESTRIAL ORGANISMS

5.0 Introduction

The assessment of the risk of SWASS to non-target organisms continues in this chapter with the determination of risk to non-target invertebrates, terrestrial wildlife, domestic animals including livestock, and terrestrial endangered and threatened species. Effects on non-target organisms may result from the direct action of the chemicals on the organism (direct effects) or from changes in predator, prey, or competition relationships (indirect effects). Both types of effects are examined in this analysis. Also included in this chapter is the determination of potential residues of DDVP and swormlure chemicals in meat (including game animals), milk, and eggs.

As discussed in the preceding chapter, there are three major portions to a determination of risk:

- hazard analysis,
- exposure analysis, and after the determination of these,
- risk analysis.

These analyses will be presented in turn as they relate to terrestrial organisms.

5.1 Hazard of SWASS Chemicals to Terrestrial Organisms

A detailed discussion of the hazards of DDVP and the swormlure chemicals to terrestrial organisms is given in Appendix A. This information is summarized below.

5.1.1 Hazard of DDVP

Values for the acute toxicity of DDVP are given in Table 5-1. The compound is extremely toxic to most birds and very toxic to rodents and rabbits. The comparatively high LD₅₀ of the compound for dogs suggests that carnivorous species may be relatively resistant to DDVP. No information is available as to the toxicity of DDVP to reptiles or amphibians.

Doses well below an LD₅₀ may result in clinical effects (tremors, emesis, dyspnea, ataxia, and convulsions) typical of organophosphate poisoning. Oral doses of 10 mg/kg for calves, 27 mg/kg for cows, 25 mg/kg for sheep, 25 - 50 mg/kg for horses, and 42 mg/kg for bears have resulted in reversible toxic effects. Because exposure of vertebrate animals to SWASS will be during one or two discrete events (see Section 5.2), chronic effects of DDVP on wildlife or domestic animals will probably not be important.

Neither DDVP nor its metabolites will accumulate in terrestrial organisms. The compound is rapidly degraded by enzymes, and the half-life in tissues is a few hours at most. The half-life in the blood (in vitro) of rabbits, pigs, and humans was found to be less than 30 minutes.

5.1.2 Hazard of Swormlure Chemicals

The acute toxicities of the various swormlure chemicals are shown in Table 5-2. Phenol and p-cresol are very toxic compounds, while the remainder are moderately toxic (Gosselin et al., 1976). There is no reason to believe that the toxicities of swormlure chemicals are additive or synergistic, except in the case of congeners (toxicologically related substances), such as phenol and p-cresol, the three fatty acids, and the two alcohols. The dose of phenol and p-cresol in a SWASS pellet constitutes a potential LD₅₀ for a rodent weighing about 0.6 kg.

TABLE 5-1
ACUTE TOXICITY OF DDVP TO TERRESTRIAL ORGANISMS

<u>SPECIES</u>	<u>EXPOSURE</u>	<u>LD₅₀ (mg/kg)</u>	<u>SOURCE</u>
MAMMALS			
Rat (male)	Oral	80	Durham et al. (1957)
(female)		56	
Rat	Subcutaneous	12	ITII (1976)
Rat (male)	Dermal	107	Durham et al. (1957)
(female)		75	
Mouse (male)	Oral	145	Wagner (1970)
(female)		135	
Mouse	Oral	124	Yamashita (1962)
Mouse	Oral	75 - 303	Ikeda (1958)
Mouse	Subcutaneous	24	Yamashita (1962)
Rabbit	Dermal	107	NIOSH (1979)
Dog	Oral	483	ITII (1976)
Dog	Oral	1090	NIOSH (1979)
BIRDS			
Chicken	Oral	15	NIOSH (1979)
Chicken	Subcutaneous	20	ITII (1976)
Quail	Unknown	1700	Vevai (1974)
Pheasant (young)	Oral	11.3	Tucker and Crabtree (1970)
Mallard (young)	Oral	7.8	Tucker and Crabtree (1970)
Duck	Oral	9.9	
Duck	Respiratory	4.7	
Wild bird	Oral	12	ITII (1976)
ARTHROPODS			
Housefly	Topical	0.6	Vevai (1974)
German Cockroach	Topical	4.0	Vevai (1974)

TABLE 5-2
MAMMALIAN TOXICITY DATA FOR SWORMLURE CHEMICALS (mg/kg)

	rat LD ₅₀	mouse LD ₅₀	rabbit LDL ₀	dog	cat	human LDL ₀
Acetic acid	3310	4960	1200	--	--	--
Butyric acid	2940	500 ¹	--	--	--	--
Valeric acid	--	3590 ³	--	--	--	--
Isobutanol	2460	--	3750	--	--	500
Sec-Butanol	6480	--	6000	--	--	--
Phenol	414	300	420	500 ¹	80 ¹	140
p-Cresol	207	344	620	--	80 ¹	--
Benzoic acid	2350	2370	2000 ²	2000 ²	2000 ²	500
Indole	1000	--	--	--	--	--
Dimethyl disulfide	813	--	--	--	--	--

Notes:

1 LDL₀

2 LD₅₀

3 subcutaneous

There is no evidence that any of the swormlure compounds accumulate in the terrestrial organisms. As with DDVP, the potential of swormlure compounds for chronic effects on wildlife or domestic animals appears negligible.

5.1.3 Overall Hazard of SWASS Pellets

There is no evidence to indicate that the toxicities of DDVP and swormlure are additive or synergistic. Organophosphate insecticides (e.g., DDVP) act upon very specific sites in the nerve cells, while swormlure chemicals exert their actions in different manners. It is reasonable to assume that the toxicity of a SWASS pellet is close to that of its most toxic component, DDVP.

About 60 mg of DDVP are present in a SWASS pellet at the time of application. If it is assumed that the toxicity of a pellet is the same as that of its DDVP component, one can calculate the weight of an animal for which the DDVP in one pellet would constitute an LD₅₀. These are shown in Table 5-3.

TABLE 5-3
WEIGHT OF AN ANIMAL FOR WHICH
ONE PELLETT CONSTITUTES AN LD₅₀

<u>SPECIES</u>	<u>WEIGHT (KG)</u>
rat, rabbit	0.8 - 1.1
mouse	0.4 - 0.5
dog, other carnivores	< 0.1
ducks	6 - 8
gallinaceous birds	3 - 5

For an animal in Table 5-3 (or animal with comparable susceptibility) weighing more than the value given in the table, the amount of DDVP in a SWASS pellet would be less than an LD₅₀. However, it must be remembered that a dose below an LD₅₀ may still be lethal to some proportion of the population. For example, it may be seen from the dose response curves in Figures A-1 and A-2, that half an LD₅₀ will still be lethal to about 5 percent of a population of mice.

One SWASS pellet contains a potential LD₅₀ of DDVP for virtually all bird species and many species of rodents. If the susceptibility of dogs to DDVP is representative of that of carnivores as a whole, then the DDVP in one pellet will be well below the LD₅₀ of even the smallest carnivores. It must be remembered that Table 5-3 is applicable to the DDVP in a SWASS pellet at the time of application. After one day, 30 percent of DDVP will have been lost from the pellet, and only half will remain after two days.

In summary, none of the SWASS compounds are cumulative; they are rapidly detoxified and excreted. As will be discussed in Section 5.2, exposure to significant quantities of DDVP or swormlure will occur only during one or two discrete events - the encountering of a SWASS pellet. Thus, the principal hazard presented by the use of SWASS to wildlife is acute toxicity, primarily because of its DDVP component.

5.2 Exposure of Non-Target Terrestrial Organisms to SWASS

There are three potential mechanisms for exposure of terrestrial organisms to SWASS chemicals:

- contact with vapors,
- direct ingestion of pellets, and
- ingestion of residues in water or food.

Exposure to vapors. DDVP and swormlure volatilize into the atmosphere, but concentrations of vapor in the air are much too small to present a hazard to vertebrate organisms. However, non-target arthropods attracted to the pellets and soil organisms in the immediate vicinity of the pellets will be exposed to lethal concentrations of DDVP vapor.

Direct ingestion of pellets. This is the most likely route for exposure of terrestrial vertebrates to significant quantities of SWASS chemicals. Some mammalian species have been observed to consume all or part of a SWASS pellet. Because the amount of DDVP in a SWASS pellet is potentially lethal to smaller vertebrates, a major portion of the risk assessment will be concerned with the effects on wildlife from ingestion of SWASS pellets in the field.

Residues in water and food. Residues of SWASS chemicals in water will be negligible. Even with successive inadvertent misapplications to cattle tanks, the concentration of DDVP in water would be less than 0.1 ppb, which is too small to have any effects on terrestrial organisms.

There is theoretically the potential for predator (including insectivorous) organisms to ingest DDVP or swormlure through residues in prey species. Residues might occur in aquatic organisms, in arthropods killed by DDVP vapors, or in small mammals which have fed upon the SWASS pellets.

The SWASS chemicals will not accumulate in aquatic organisms, although fish can concentrate the phenols by a factor of two or three. Concentrations of the chemicals in organisms will be the same order of magnitude as the concentrations in water, which will be insignificant.

There is the potential for insectivorous animals to ingest DDVP through dead flies or other insects. However, the amounts ingested would be insignificant. For instance, if a fly absorbs

an LD₅₀ (about 1 mg) of DDVP before dying and if there is no degradation of the compound in the insect by enzymes (there most likely would be), then an insectivorous bird would have to consume 10 times its weight in flies at one time to ingest an LD₅₀, assuming an LD₅₀ of about 12 mg/kg.

There is also the theoretical potential for residues in small mammals which might be killed after ingestion of an entire SWASS pellet (see Section 5.3.2). The carcasses would be available to scavenging carnivores such as vultures and coyotes. However, as discussed in Section 5.3.2, it has not been demonstrated conclusively that wildlife will voluntarily ingest a lethal portion of a SWASS pellet. Moreover, because of the rapid hydrolysis of DDVP by enzymes, most of the DDVP will have disappeared by the time a dead or dying animal is consumed. For these reasons, the exposure of carnivorous species to DDVP through ingestion of small mammals killed by SWASS pellets is not expected to be important.

In summary, the routes of exposure which are of primary interest in the assessment of direct effects on non-target terrestrial organisms are:

- exposure of non-target invertebrates in the vicinity of the pellets to DDVP vapors, and
- direct ingestion of SWASS pellets by small vertebrates.

The likelihood and extent of exposure from these routes will be discussed in more detail in the next section, the risk assessment.

5.3 Risk of the Use of SWASS to Non-Target Terrestrial Organisms

As discussed in Section 5.2, the species most at risk from direct effects of SWASS will be non-target invertebrates attracted to or residing in the vicinity of the pellets and small vertebrates who might eat the pellets.

Also of concern in the assessment of risk are indirect effects on terrestrial organisms. An indirect effect is an effect on a particular species resulting from a change in habitat, a change in abundance of predators, prey, or competitors, or some other alteration to the ecosystem in which a species resides. Of particular concern to this evaluation is the possibility of effects on insectivorous species resulting from the decrease of insects in SWASS areas.

5.3.1 Risk to Invertebrate Species

Soil organisms. Garcia Acosta et al. (1980) found that DDVP will diffuse into the soil around a SWASS pellet to a radius of no more than 50 cm. and that concentrations of up to 17.4 ppm were reached in the soil. Some mortality of soil organisms would be expected, but effects would be extremely local and with the wide dispersion of the pellets, insignificant.

Non-target species. The chemical attractant in the SWASS pellet, swormlure-2, is quite specific to the screwworm flies, both the "primary" screwworm (Cochliomyia hominivorat) and the so-called secondary screwworm (C. macellaria), which often infests the bad wounds caused by the former. The swormlure chemicals are naturally-occurring constituents of decomposing animal matter, so it is not surprising that most of the non-target insects attracted to the pellets breed in carrion and dung.

In a study conducted by USDA (Peterson et al., 1979), dead insects were collected from the vicinity of SWASS pellets at 319 sites in 19 study areas in Texas, New Mexico, Arizona, and Mexico. Table 5-4 shows the results.

TABLE 5-4
DEAD INSECTS COLLECTED IN THE
VICINITY OF SWASS PELLETS

	Peterson et al. (1979)			Garcia Acosta et al.(1980)	
	<u>NUMBER</u>	<u>PERCENT</u>	<u>PERCENT</u>	<u>PERCENT</u>	<u>PERCENT</u>
Diptera	4338		93.5		88.8
Calliphoridae	3216	69.3		18.7	
Sacophagidae	426	9.2		30.0	
Anthomyiidae	284	6.1		-	
Muscidae	179	3.9		40.1	
Others	235	5.1		-	
Hymenoptera	229		4.9		9.4
Formicide	227	4.9		9.4	
Others	<u>73</u>		<u>1.6</u>		<u>1.8</u>
TOTAL	4640		100		100

Diptera (true flies) comprised 93.5 percent of the dead insects. Of the Calliphoridae (blow flies) collected at SWASS pellets, C. macellaria comprised 71 percent, or almost half of all the insects collected at the pellets. Only 1.8% of the insects were screwworms (C. hominovorax), but they are relatively rare in nature. Worker ants comprised 99 percent of the Hymenoptera (ants, bees, wasps, etc.) collected. Only one bee was found, and it was not a honeybee.

A similar study was conducted by the Mexican government near Aldama, Mexico (Garcia Acosta et al., 1980), and the results are shown in Table 5-4. The results are comparable to those of Peterson et al. (1979), although a much larger portion

of the Diptera were comprised of Muscidae (house flies and relatives). Again, almost all of the Hymenoptera were ants.

The above studies suggest that most of the mortality to non-target insects would be limited to three or four families of flies. Many species of calliphorids, sarcophagids (flesh flies), and muscids are considered to be pests. C. macellaria and some species of sarcophagids may parasitize livestock. However, the low numbers of flies collected (an average of only 14 per site) in the USDA study suggest that populations of non-target flies (except perhaps C. macellaria) will not be significantly affected by the use of SWASS. Because of the biotic potential of insects, any effects would be short term.

During a USDA-sponsored ecological study near Aldama, Mexico (Hightower, 1979), tests were conducted to determine whether populations of non-target insects were affected by SWASS. Treatment and control areas were delineated, and insects were trapped using fruit and liver baits. No significant differences between treatment and control areas were found in populations of Diptera, Hymenoptera, Coleoptera (beetles) or Hemiptera (true bugs).

Indirect effects on insectivores. Several species of birds, reptiles, and amphibians subsist almost entirely on insects and other arthropods. Although populations of three or four families of flies might be temporarily reduced by SWASS, overall populations of flies (and other orders of insects as well) do not appear to be significantly affected by the use of SWASS. Thus, insectivorous species are not likely to be indirectly affected by the SWASS program.

5.3.2 Risk to Vertebrate Species

The only significant risk to vertebrates from the use of SWASS would be through ingestion of pellets. In order to assess the risks to vertebrates, it must be known:

- whether or not a species will voluntarily ingest a pellet and, if so,
- whether there is enough toxicant in the pellet to cause harm.

There is very little information available concerning the voluntary acceptance of SWASS pellets by vertebrate species. The information consists of a few observations in the field and some limited pen tests.

In studies conducted by USDA (Peterson et al., 1979), penned goats and sheep refused SWASS pellets, as did dogs, cats, and cows. A rooster pecked at a pellet but did not ingest any of it. One pellet was eaten by a hog.

During the same studies, traps at 46 sites were baited with SWASS pellets. Six animals were captured, four wood rats, a Mexican ground squirrel, and a cottontail. The ground squirrel had eaten the pellet, but the animal showed no signs of distress when released from the trap. The pellets in the other traps were either partially consumed or intact.

During the USDA non-target insect study (Peterson et al., 1979), SWASS pellets and adjoining areas were observed for signs of feeding and other evidence of visits by vertebrates. Signs of systematic feeding were rarely seen, but it was observed that occasionally pellets had disappeared, moved, or had been chewed and dropped. About 10 percent of the pellets disappeared after one week, but many of these were recovered uneaten at some distance from the original site.

In the USDA study at Aldama, Mexico (Hightower, 1979), one opossum and one cotton rat were given a SWASS pellet along with adequate food and water. Each animal ingested a small portion of the pellet, with no ill effects observed. Each refused the pellets during a second trial.

No evidence of mortality to wildlife has been observed during SWASS studies or in operational programs.

As seen in Section 5.1.3, the potential for harm from ingestion of a SWASS pellet depends on the amount of toxicant in the pellet relative to the size of the animal that ingests it. Thus, the weight of the animal can be compared with the values in Table 5-3 to determine the likelihood of harm after ingesting a pellet.

Of the small mammals which have been trapped with pellets or observed feeding on them, opossums average 2.5 kg in weight, cottontails 1 - 1.5 kg, ground squirrels 0.5 kg, wood rats 0.2 - 0.4 kg, and cotton rats 0.1 - 0.2 kg. Opossums are large enough that one pellet would not be lethal in most cases. Rats and mice are small enough that one pellet would almost always be lethal if ingested at once. One pellet appears to contain slightly less than an LD₅₀ for cottontails. Although the LD₅₀ of DDVP for ground squirrels is not known, the toxicant in one pellet would constitute an LD₅₀ (50% would be expected to die) if the susceptibility were comparable to that of mice.

It must be remembered, however, that the discussion above pertains to potential lethality. A lethal dose of DDVP must be consumed almost at once, because the half-life in tissues is less than 30 minutes and perhaps less than 15 minutes. Thus, an animal nibbling on a pellet over the course of an hour or so might not ingest a lethal dose. Moreover, as the DDVP volatilizes from a pellet through time, the toxicity of a pellet will decrease accordingly. After one day, about 30% of the DDVP will have disappeared.

The extent of the risk to small mammals from the use of SWASS remains unclear. Although toxicity data suggest a potential for mortality, this has not been observed in the few feeding studies or in the field. Feeding on the pellets does not

appear to be a common occurrence. It seems reasonable to conclude that mortality of small mammals from feeding on SWASS pellets would be an isolated occurrence, limited mainly to smaller scavenging rodents such as wood rats and cotton rats.

Except for certain endangered and threatened species discussed in Section 5.5, small rodents generally have a very high reproductive potential, and mortality must be very high to have a significant effect on populations. Because the mortality (if any) from SWASS would be isolated, and because of the wide dispersion of the pellets and the small home ranges of these mammals, the use of SWASS will have no significant effects on the populations of these species.

It is possible that scavenging carnivores such as skunks and ringtails or omnivores such as javelinas or armadillos might be attracted to SWASS pellets, although their presence around pellets has not been observed. Dogs (and presumably other canids) and cats refuse to eat the pellets. The size of these species (0.5 - 1 kg for spotted skunks, 2 - 3 kg for striped skunks, 1 kg for ringtails, 4 - 8 kg for armadillos and 16 - 30 kg for javelinas) and the relative resistance of carnivores and swine to DDVP suggests that ingestion of a pellet would not normally be lethal to these species.

With the exception of pigs, livestock refuse to eat SWASS pellets. This suggests that grazing mammals such as antelope and deer will also refuse SWASS pellets. The size of pigs and their relative resistance to DDVP is such that even in the unlikely event of exposure to SWASS, no harmful effects would be expected on these animals.

One SWASS pellet is potentially lethal to virtually all wild bird species. With the exception of vultures, however, the sense of smell is not important to birds (Brown and Amadon, 1968). Thus, it is not expected that birds would recognize a

pellet as food nor that they would find a pellet palatable. Reptiles and amphibians prefer live food, and it is unlikely that they would recognize a SWASS pellet as food.

In summary, there is the potential for mortality to small mammals from the use of SWASS, primarily scavenging rodents such as wood rats and cotton rats. It is expected that mortality would be an isolated occurrence and that populations would probably not be affected. Scavenging carnivores and omnivores might be attracted to SWASS pellets, but their size and relative resistance to DDVP are such that ingestion of a SWASS pellet would not normally be lethal. No effects are expected on livestock, grazing wildlife, birds, reptiles, or terrestrial amphibians.

5.4 Residues in Meat, Milk, and Eggs

In order to determine human ingestion of SWASS chemicals, the potential residues of these chemicals in foods, particularly meat, milk, and eggs, must be known.

DDVP disappears from tissues so rapidly that residues in meat, milk, or eggs would not be expected even if an animal ingested a pellet. Potter et al. (1973) found that DDVP rapidly disappears from the blood of sows and piglets with no organochlorine residue accumulation in the tissues. Ivey and Eschle (1970) detected no residues in milk or tissues in dairy cattle which were sprayed for 31 days with 2 oz. of a 1% solution of DDVP. Milk from dairy cows accidentally dosed with 45 times the amount of DDVP used in the Ivey and Eschle study was bioassayed to determine DDVP contamination. In the bioassay houseflies were exposed to milk taken from cows which had exhibited signs of clinical intoxication. The flies were exposed to milk taken immediately after dosing and to milk taken about 12 hours later, and no significant increase in fly mortality was observed (Knapp and Graden, 1964). The LD_{50} for houseflies is .6 mg/kg.

Title 21 CFR 556.180 sets the tolerance of 0.1 ppm for negligible residues of DDVP in edible swine tissue. Title 21 CFR 193.140 sets 0.5 ppm as the allowable residue on packaged or bagged nonperishable processed food. These are FDA regulations. Applicable EPA residue tolerances for DDVP are 0.02 ppm in meat, fat, milk and meat byproducts of cattle, goats, horses, and sheep and 0.05 ppm in eggs and poultry (Title 40 CFR 180.235).

Residues of swormlure in meat, milk, and eggs should likewise be negligible. Mehta et al. (1978) found that 60 - 80% of doses of phenol up to 25 mg/kg were excreted within 24 hours. Phenol is both metabolized and excreted unchanged by rabbits (in Gosselin et al., 1976). A pig excreted most of a percutaneous dose of phenol (90 mg/kg) within eight hours (Pullin et al., 1978). Since p-cresol is similar to phenol toxicologically and chemically, it would be expected to behave in the same manner. The other swormlure chemicals are products of natural decomposition and fermentation processes, and there is no reason to believe that they would not be rapidly metabolized or eliminated.

As seen in the previous section, most livestock (cattle, sheep, and goats) refuse SWASS pellets, and it is expected that large grazing mammals such as deer would also refuse them. Chickens are not expected to ingest the pellets, nor are game birds such as doves or quail. It is possible that DDVP and the swormlure chemicals might be ingested by livestock and wildlife by drinking from a cattle tank in which a SWASS pellet had landed. However, the extremely low concentrations in the water (less than 0.1 ppb for DDVP) and the rapid rate of metabolism of the chemicals are such that residues in the meat of these species would be essentially zero at the time of consumption. The edible products from these species are not expected to contain residues of DDVP or swormlure.

Pigs will apparently eat SWASS pellets, although it is unlikely the animals would be found on treated rangelands. Javelinas likewise would be expected to eat SWASS pellets. Rabbits may be attracted to pellets, but it is unclear whether or not they will feed on them. In any event, because of the short half-lives of DDVP in these species (25 minutes or less in pigs, 2 minutes or less in rabbits), residues in the meat of these animals will be negligible. To illustrate this point, if a pig ingests an entire SWASS pellet, the residue in its tissues will be below the FDA tolerance level in less than two hours. Residues of swormlure in these species should likewise be negligible.

5.5 Risk to Terrestrial Endangered and Threatened Species

There are several species of terrestrial wildlife occurring in the study areas which are listed by the Federal or state governments as endangered or threatened. These species are shown in Table 5-5.

5.5.1 Federally Listed Terrestrial Endangered and Threatened Species

Five species or subspecies of mammals, eight species of birds, and one reptile species are listed by the Federal government and occur in the study areas. None of these species appear likely to eat a SWASS pellet. Of the mammals, the jaguar and jaguarundis are felids, the gray wolf is a canid, and the pronghorn is a large grazing mammal. As was discussed in Section 5.3.2, dogs, cats, and livestock refused to eat SWASS pellets. Thus, it is reasonable to assume that the endangered mammals would also refuse SWASS pellets. Moreover, these species are so large that even if a pellet were to be ingested, no harmful effects would be expected.

Of the bird species, the brown pelican, Eskimo curlew, and whooping crane are water birds and will not be exposed to SWASS pellets if they are applied in accordance with the

TABLE 5-5
TERRESTRIAL ENDANGERED AND THREATENED SPECIES

Mammals - National Listing

<u>Common Name</u>	<u>Latin Name</u>	<u>Ecoregion</u>	<u>Status</u>
Jaguar	<u>Panthera onca</u>	1M	E
Jaguarundi	<u>Felis yagouroundi tolteca</u>	1M	E
Sonoran pronghorn (AZ)	<u>Antilocapra americana sonoriensis</u>	1M	E
Gray wolf	<u>Canis lupus</u>	1, 2, 3M	E
Jaguarundi (TX)	<u>Felis yagouroundi cacomitli</u>	3M	E

Mammals - State Listing

<u>Common Name</u>	<u>Latin Name</u>	<u>State Listed</u>	<u>Ecoregion</u>	<u>Status</u>
Arizona shrew	<u>Sorex arizonae</u>	NM	1	T
Coatimundi	<u>Nasua narica molaris</u>	NM	1	T
Mexican wolf	<u>Canis lupus baileyi</u>	AZ	1M	E
River otter	<u>Lutra canadensis</u>	NM	1M	E
Southern pocket gopher	<u>Thomomys umbrinus emotus</u>	NM	1	T
Western mastiff bat	<u>Eumops perotis californicus</u>	NM	1	T
White-sided jackrabbit	<u>Lepus callotis gaillardi</u>	NM	1	E
Bighorn sheep	<u>Ovis canadensis</u>	TX	1, 2	E
Desert bighorn	<u>Ovis canadensis mexicana</u>	AZ	1, 2	T
Ocelot	<u>Felis pardalis</u>	TX	1, 2, 3	E
Southern (or Lesser) yellow bat	<u>Lasiurus ega xanthinus</u>	NM, TX	1, 2, 3M	T
Nelson's pocket mouse	<u>Perognathus nelsoni canescens</u>	NM	2	T
Spotted bat	<u>Euderma maculatum</u>	TX	2	T
Tularosa black-tailed prairie dog	<u>Cynomys ludovicianus spp.</u>	NM	2	T

Birds - National Listing

<u>Common Name</u>	<u>Latin Name</u>	<u>Ecoregion</u>	<u>Status</u>
American peregrine falcon (AZ, NM, TX)	<u>Falco peregrinus anatum</u>	1, 2, 3	E
Bald eagle (AZ, NM, TX)	<u>Haliaeetus leucocephalus</u>	1, 2, 3M	E
Brown pelican (NM, TX)	<u>Leptopelicanus occidentalis carolinensis</u>	2, 3	E
Eskimo curlew	<u>Numenius borealis</u>	2, 3	E
Whooping crane	<u>Limnogeranus americanus</u>	2, 3M	E
Arctic peregrine falcon (TX)	<u>Falco peregrinus tundrius</u>	3M	E
Attwater's greater prairie chicken	<u>Tympanuchus cupido attwateri</u>	3	E

Birds - State Listing

<u>Common Name</u>	<u>Latin Name</u>	<u>State Listed</u>	<u>Ecoregion</u>	<u>Status</u>
Baird's sparrow	<u>Ammodramus bairdii</u>	NM	1	T
Beardless flycatcher	<u>Camptostoma lamberbe ridgwayi</u>	AZ, NM	1	T
Bell's vireo	<u>Vireo bellii</u>	AZ, NM	1	T
Black-bellied whistling duck	<u>Dendrocygna autumnalis fulgens</u>	AZ	1M	T
Broad-billed hummingbird	<u>Cyanthus latirostris</u>	NM	1	T
Buff-breasted flycatcher	<u>Empidonax fulvifrons pygmaeus</u>	NM	1	E
Buff-collared nightjar or Ridgway's whip-poor-will	<u>Caprimulgus ridgwayi</u>	NM	1	T
Coppery-tailed trogon	<u>Trogon elegans canescens</u>	NM	1	E
Gila woodpecker	<u>Melanerpes uropygialis</u>	NM	1	T
McCown's longspur	<u>Calcarius mccownii</u>	NM	1	T
Mexican turkey	<u>Meleagris gallopavo mexicana</u>	NM	1	T
Sulfur-bellied flycatcher	<u>Myiodynastes luteiventris swarthi</u>	NM	1	T
Yellow-eyed junco	<u>Junco phaeonotus palliatus</u>	NM	1	T
Varied bunting	<u>Passerina versicolor</u>	NM	1	T
Thick-billed kingbird	<u>Tyrannus crassirostris pompalis</u>	NM	1	T
Violet-crowned hummingbird	<u>Amazilia violiceps ellioti</u>	NM	1	T
White-eared hummingbird	<u>Hylocharis leucotis</u>	NM	1	T
Mississippi kite	<u>Ictinia mississippiensis</u>	NM	1, 2	T
Olivaceous comorant	<u>Phalacrocorax olivaceus</u>	NM	1, 2	T
Aplomado falcon	<u>Falco femoralis septentrionalis</u>	NM, TX	1, 2, 3M	E, T
Black hawk	<u>Buteogallus a. anthracinus</u>	AZ, NM, TX	1, 2, 3	T
Gray hawk	<u>Buteogallus nitidus maximus</u>	AZ, NM, TX	1, 2, 3M	E, T
Carcara	<u>Polyborus cheriway auduboni</u>	NM	2	E
Interior Least tern	<u>Sterna albifrons anthalassos</u>	NM, TX	2, 3	T, E
Least tern	<u>Sterna albifrons antillarum</u>	TX	2, 3M	T
Osprey	<u>Pandion haliaetus carolinensis</u>	TX	2, 3M	T
Swallow-tailed kite	<u>Elanoides forficatus</u>	TX	2, 3M	T
White-faced ibis	<u>Plegadis chihi</u>	TX	2, 3M	T
White-tailed hawk	<u>Tachytriorchis albicaudatus</u>	TX	2, 3M	T

TABLE 5-5 (Continued)
TERRESTRIAL ENDANGERED AND THREATENED SPECIES

Birds - State Listing (Continued)

Common Name	Latin Name	State Listed	Ecoregion	Status
Wood stork (or ibis)	<u>Mycteria americana</u>	TX	2, 3M	T
One-tailed hawk	<u>Buteo albonotatus</u>	TX	2, 3M	T
Rufous owl	<u>Glaucidium brasilianum</u>	TX	3M	T
Golden-cheeked warbler	<u>Dendroica chrysoparia</u>	TX	3	T
Reddish egret	<u>Dichromanassa r. rufescens</u>	TX	3	T

Reptiles - National Listing

Common Name	Latin Name	Ecoregion	Status
New Mexican ridgenosed rattlesnake	<u>Crotalus willardi obscurus</u>	1	T

Reptiles - State Listing

Common Name	Latin Name	State Listed	Ecoregion	Status
Junco lizard	<u>Sceloporus scalaris</u>	NM	1	T
Desert tortoise	<u>Gopherus agassizi</u>	AZ	1	T
Dixons whiptail lizard	<u>Cnemidophorus dixonii</u>	NM	1	T
Giant spotted whiptail lizard	<u>Cnemidophorus burti stictogrammus</u>	NM	1	T
Mountain skink	<u>Eumeces callicephalus</u>	NM	1	T
Narrow-headed garter snake	<u>Thamnophis rufipunctatus</u>	NM	1	T
Monora coachwhip	<u>Masticophis flagellum cingulum</u>	NM	1	T
Western massauga	<u>Sistrurus catenatus</u>	AZ	1	E
Monora monster	<u>Heloderma suspectum</u>	AZ, NM	1, 2M	T, E
Monora mountain kingsnake	<u>Lampropeltis p. pyromelana</u>	NM	1, 2	T
Baird's rat snake	<u>Elaphe obsoleta bairdi</u>	TX	2M	T
Big Bend canyon lizard	<u>Sceloporus merriami annulatus</u>	TX	2M	T
Big Bend gecko	<u>Coleonyx reticulatus</u>	TX	2M	T
Big Bend milk snake	<u>Campropeltis triangulum celaenops</u>	TX	2M	T
Gray-banded king snake	<u>Lampropeltis mexicana alterna</u>	TX	2M	T
Bottled rock rattlesnake	<u>Crotalus l. lepidus</u>	NM	2	T
Mountain short horned lizard	<u>Phrynosoma douglassi hernandesi</u>	TX	2	T
Pecos western ribbon snake	<u>Thamnophis proximus diabolicus</u>	NM	2	T
Residio canyon lizard	<u>Sceloporus merriami annulatus</u>	TX	2	T
Black rattlesnake	<u>Crotalus lepidus</u>	TX	2M	T
Sanddune sagebrush lizard	<u>Sceloporus graciosus arenicolous</u>	NM	2	T
Texas lyre snake	<u>Trimorphodon biscutatus wilkinsoni</u>	TX	2M	T
Trans-Pecos copperhead	<u>Agkistrodon contortrix pictigaster</u>	NM, TX	2M	T
Trans-Pecos rat snake	<u>Elaphe subocularis</u>	TX	2M	T
Texas horned lizard	<u>Phrynosoma cornatus</u>	TX	2, 3M	T
Black-striped snake	<u>Coniophanes i. imperialis</u>	TX	3	T
Mexican milk snake	<u>Lampropeltis triangulum annulata</u>	TX	3M	T
Northern cat-eyed snake	<u>Leptodeira s. septentrionalis</u>	TX	3M	T
Reticulate collared lizard	<u>Crotaphytus reticulatus</u>	TX	3M	T
Speckled racer	<u>Drymobius m. margaritiferus</u>	TX	3M	E
Texas indigo snake	<u>Drymarchon corais erebennus</u>	TX	3M	T
Texas tortoise	<u>Gopherus belandieri</u>	TX	3M	T

Insects - National Listing

NONE

Insects - State Listing

NONE

Key: () = Federally listed species also on state lists

AZ = Arizona

NM = New Mexico

TX = Texas

M = extending into Mexico

Ecoregions 1, 2, 3 - see Figure 1

E = Endangered: any species in danger of extinction throughout all or a significant portion of its range.

T = Threatened: any species likely to become an endangered species within the foreseeable future throughout all a significant portion of its range.

restrictions. Because raptors hunt by sight, and because roosters find SWASS pellets unpalatable (see Section 5.3.2), it appears very unlikely that the peregrine falcon, bald eagle, or prairie chicken would eat a SWASS pellet. The ridge-nosed rattlesnakes eat lizards and small rodents and would not be expected to recognize a SWASS pellet as food.

Thus, the use of SWASS is expected to have no effects on Federally listed terrestrial endangered and threatened species.

5.5.2 State-Listed Terrestrial Endangered and Threatened Species

The discussions in Sections 5.3.2 and 5.5.1 concerning the risk of SWASS to terrestrial wildlife are applicable to state-listed species as well. Thus, the birds and reptiles are not likely to recognize SWASS pellets as food.

Of the mammals, bats and shrews prefer live insects and arthropods, and would not be expected to eat a pellet. The sheep, Mexican wolf, and ocelot are expected to refuse the pellets, and the otter will not be exposed to SWASS because of the restrictions concerning waterways. Of the three rodents on the list, the pocket gopher is strictly herbivorous, and the pocket mouse and prairie dog are almost entirely herbivorous. Thus, these species would not normally be expected to eat a SWASS pellet. Prairie dogs average 1.5 kg in weight, so the toxicant in a SWASS pellet is normally much less than a lethal dose (see Table 5-3). Nelson's pocket mouse is relatively secure in Mexico (Hubbard et al., 1979) and is on New Mexico's list on the basis of one sighting in 1954 in Eddy County (in an area in which SWASS is restricted).

The jackrabbit and coatimundi might be attracted to the pellets, but the size of these species (2 - 3 kg for the jackrabbit, 11 kg for the coati) is such that even should a pellet be ingested, mortality would not be expected.

Thus, the use of SWASS is expected to have no effect on state-listed endangered or threatened species.

5.6 Summary

- Some mortality of soil organisms would be expected from the use of SWASS, but effects will occur only in the immediate vicinity of the pellets (within 50 cm.). Given the wide dispersion of the pellets, these effects will be insignificant.
- There will be some mortality of non-target insects, primarily Diptera in the families Calliphoridae, Sarcophagidae, and Muscidae, many of which are considered pest species. Effects on these species should be short-term. Bees are not expected to be affected.
- Because populations of non-target insects should not be significantly affected by the use of SWASS, no indirect effects are expected on insectivorous species.
- There is the potential for mortality to small mammals which might ingest SWASS pellets. Those species most at risk are small scavenging rodents such as cotton rats and wood rats. It is expected that mortality would be an isolated occurrence and that populations would not be affected. Scavenging carnivores and omnivores might be attracted to SWASS pellets, but their size and relative resistance to DDVP are such that ingestion of a SWASS pellet would not normally be lethal. No effects are expected on livestock, grazing wildlife, birds, or reptiles.
- No residues of DDVP or swormlure are expected in the meat of cattle, sheep, goats, grazing wildlife, poultry, or game birds, or in milk and eggs. Pigs, javelinas, and rabbits might ingest SWASS pellets but because of the rapid metabolism of DDVP and the swormlure chemicals, residues in the meat of these species will be negligible.

- The use of SWASS is expected to have no effects on members of endangered or threatened terrestrial species.

CHAPTER 6

EFFECTS ON HUMANS

6.0 Introduction

This is the final chapter dealing with the risk to organisms from the use of SWASS. As in the preceding chapters, the assessment of risk entails an analysis of the hazards of the SWASS chemicals and the determination of the extent and likelihood of exposure to the chemicals.

It must be noted that this evaluation is concerned with effects on humans which might occur after SWASS has been applied. It is not concerned with the risk to humans exposed to the chemicals during formulation and manufacture of the pellets nor with personnel involved in the transportation and application of the pellets.

6.1 Hazard of SWASS Chemicals to Humans

In addition to the insecticide DDVP, the chemicals comprising swormlure are also toxic. Phenol and p-cresol are "very toxic" in the classification scheme of Gosselin et al. (1976), while the remaining chemicals are "moderately toxic". As was discussed in Section 5.1, the overall acute toxicity of a SWASS pellet is probably comparable to that of its most toxic component, DDVP.

A detailed review of the literature concerning the toxicity of DDVP and the swormlure chemicals to humans is given in Appendix A. This information is summarized in the following sections.

6.1.1 Hazard of DDVP to Humans

Acute toxicity data of DDVP for mammalian species are given in Table 5-1. Monkeys treated with daily oral doses of DDVP at 20, 40, and 80 mg/kg experienced none of the clinical symptoms typical of organophosphate poisoning, although blood cholinesterase activity was inhibited. Because the susceptibility of humans should be comparable, the LD₅₀ of DDVP for humans is probably high relative to the LD₅₀'s of rats, mice, and rabbits. The lowest published lethal dose (LDL₀) for humans is 50 mg/kg. No clinical abnormalities were observed in human males exposed to 52 mg/m³ in the air for 62 minutes.

Chronic exposure to DDVP (as in the case of continuous exposure to household pest strips or the daily ingestion of residues) may result in the depression of plasma cholinesterase levels. The no-effect level (NOEL) of chronic exposure to DDVP was determined to be 0.033 mg/kg for effects on plasma cholinesterase (FAO/WHO, 1971).

DDVP will not accumulate in humans, the half-life in the body probably being less than 30 minutes.

The compound is under pre-RPAR (Rebuttable Presumption Against Registration) review by the U. S. Environmental Protection Agency for possible mutagenicity, oncogenicity, reproductive effects and fetotoxicity. The recent literature suggests that DDVP is not mutagenic in mammals, nor are its metabolites when generated in vivo. DDVP does not appear to be carcinogenic, although the compound is scheduled for a carcinogenesis bioassay in DHEW's National Toxicology Program (NTP) in FY 1980. Although one study (Kimbrough and Gaines, 1968) concluded that DDVP is slightly teratogenic to Sherman strain rats when given intraperitoneally (ip) on the 11th day of gestation, subsequent studies found no evidence that the compound produces reproductive disorders or that it is fetotoxic. In fact, DDVP added to daily swine feed aids in improving litter production efficiency.

6.1.2 Hazard of Swormlure to Humans

The acute toxicities of the chemicals in swormlure are given in Table 5-2. The LD₅₀'s for humans are not known, but they are probably comparable to those of rats. Certain individuals may be particularly susceptible to one or more of these chemicals. Lowest published lethal doses (LDL₀'s) for humans of isobutanol, phenol, and benzoic acid are also given in Table 5-2. No information was found concerning synergisms among the swormlure chemicals, but effects of congeners (toxicologically similar chemicals) might be expected to be additive. Phenol and p-cresol are congeners as are the two butanol isomers and the three fatty acids (acetic, butyric, and valeric acids).

Swormlure chemicals are not known to accumulate in the body.

Phenol, p-cresol, isobutanol, and indole are listed in the NIOSH registry (NIOSH, 1978) as possibly causing carcinomas or neoplasms. No evidence of systematic carcinogenicity has been found for phenol or p-cresol (Dean, 1978). In a recent National Cancer Institute carcinogenesis bioassay, phenol was found to be not carcinogenic to rats or mice. There is evidence that indole is both a promoter and inhibitor of bladder carcinomas. Isobutanol was listed in the registry because of one study (Gibel et al., 1975) showing an increased incidence of tumors in 19 rats exposed to twice-weekly oral applications of 200 mg/kg until 29 g. were taken. Neither of the latter compounds has been a subject of an IARC (International Agency for Research on Cancer) evaluation, nor have they been nominated for testing in the National Toxicology Program.

6.2 Exposure of Humans to SWASS Chemicals

The mechanisms by which humans might ingest DDVP or swormlure after an application of SWASS are as follows:

- inhalation,
- residues in water,
- residues in food, and
- direct ingestion of a pellet.

Inhalation is not expected to be significant because of the small amount of chemicals in the pellets and their extreme dispersion. Using the equation in Section 3.3.2, it can be shown that a fresh pellet will emit about 3.6 mg of DDVP during the first hour, about 3.0 mg during the second hour, and so forth, assuming the DDVP in the pellet disappears exponentially. If all the DDVP emitted in the first hour is confined in an area only 10 m X 10 m X 10 m, the concentration in the air would be only 0.0036 µg/l. This is three orders of magnitude below the industrial threshold concentration (TLV) of 1 µg/l, which has a built-in safety factor. Of course, the DDVP from SWASS pellets will be dispersed over many acres, and it will be rapidly hydrolyzed as well.

Residues in drinking water are expected to be insignificant. The pellets are applied on range land, and cattle tanks and ponds are not normally sources of human drinking water. Because the aerial application of SWASS is prohibited within 1/2 mile of streams and lakes, there will be negligible residues in surface water supplies. Contamination of ground water is not likely because DDVP adsorbs to soil particles and is hydrolyzed in solution, and all of the SWASS chemicals will be rapidly degraded by soil organisms.

No residues of SWASS chemicals are expected in the meat of livestock, grazing wildlife (such as deer), chickens, or game birds, or in milk and eggs (see Section 5.4). Although pigs and their relatives and rabbits might ingest SWASS pellets, residues in their meat will be negligible, well below the FDA and EPA tolerance limits.

The acceptable daily intake (ADI) for DDVP has been set at 0.004 mg/kg/day (FAO/WHO, 1971), based on the no effect level for plasma cholinesterase depression discussed above. A 70 kg man would have to drink 2800 liters (over 650 gallons) of water from a contaminated livestock tank to ingest this amount. Residue tolerances in animal products are based on the ADI, so the fact that DDVP residues in meat will be well below these limits indicates that amounts of DDVP ingested through meat will be well below the ADI.

No tolerance limits were found concerning permissible residues of the swormlure chemicals in foods. However, it must be kept in mind that all of the swormlure chemicals are natural products of fermentation and decomposition processes. There are many opportunities for "everyday" exposure to the four swormlure compounds whose chronic effects were discussed above. Phenol is found in many domestic products, including inks and dyes, school paste, disinfectants, and throat remedies (some mouthwashes are 1.4 - 2.0% phenol). P-cresol occurs naturally in many essential oils, including ylang-ylang and jasmine oil, and the compound is used in disinfectants. Both phenol and p-cresol occur in cigarette smoke and burning rubbish. Indole occurs naturally in feces and in many flower scents including jasmine and orange blossoms. It is also found in cigarette smoke. Isobutanol is found in fusel oil and is a product of natural fermentation processes. Gibel et al. (1975) found isobutanol concentrations to be 0.11 ppm in vodka and gin, 0.21 ppm in scotch, 0.25 ppm in bourbon, and 0.34 ppm in cognac.

The only mechanism for exposure of humans to significant quantities of SWASS chemicals appears to be direct ingestion of a SWASS pellet. The chances of this occurring appear remote. SWASS is applied only on rangelands in lightly populated areas and not in the vicinity of buildings. The pellets are widely scattered (one per 4.3 acres), and they are quite difficult to

locate once dropped. Moreover, the odor of the pellets is very disagreeable, and it appears unlikely that a human would voluntarily eat a pellet.

6.3 Risk of SWASS to Humans

As seen in the preceding section, the vapors from the SWASS pellets and the potential residues in water or meat are of such negligible amounts as to present virtually no risk to humans. The only potential mechanism for encountering significant quantities of DDVP or swormlure is through ingestion of a SWASS pellet. Thus, the principal hazard of SWASS to humans is the acute toxicity from oral ingestion of DDVP. The chronic hazards appear to be insignificant given the limited exposure to the compounds.

As mentioned previously, the overall acute toxicity of a SWASS pellet is probably comparable to that of its most toxic component, DDVP. The amount of toxicant in a fresh pellet (60 mg of DDVP) is actually rather small when compared with the size of a human. For example, assume a child weighing 10 kg (22 lbs.) eats an entire SWASS pellet. An oral dose equivalent to 6 mg/kg will have been ingested. It was seen in Section 6.1.1 that the LD₅₀ for humans is probably higher than that for mice. If a conservative estimate of 150 mg/kg is used (since children tend to be more sensitive to toxins), the DDVP in a fresh SWASS pellet is only 4 percent of an LD₅₀; it is only 12.5% of the lowest published lethal dose (LDL₀), which is 50 mg/kg.

As was discussed in Section 6.1, doses of up to 50 mg/kg in monkeys produced no clinical signs of intoxication, and the only observed effect was a depression of plasma cholinesterase levels. Thus it is likely that a child ingesting a SWASS pellet will experience no symptoms of distress. When it is considered that it is highly unlikely a SWASS pellet will be ingested by a human, it may be seen that the risk to humans from the use of SWASS is negligible.

6.4 Summary

- Exposure of humans to SWASS chemicals through inhalation or residues in food and water will be insignificant.
- The only mechanism for exposure of humans to significant quantities of SWASS chemicals is direct ingestion of a pellet. Because SWASS is applied only in sparsely inhabited rangeland, because its odor is very disagreeable, and the amount of DDVP in a pellet is small, the risk to humans from the use of SWASS appears negligible.

CHAPTER 7

PROGRAM CONFLICT AND OTHER ENVIRONMENTAL-SOCIAL IMPACTS

7.0 Introduction

The EEP methodology takes into consideration the impacts stemming from wide area pesticide applications on aquatic organisms, wildlife, non-target agriculture, endangered and threatened species, humans (through ingestion), other government programs, and the environmental-social settings of persons in the application areas. The previous chapters evaluated all but the latter two areas of concern. This chapter comprises the evaluations performed to determine the effect the SWASS treatment program has on government programs and the environmental-social settings for inhabitants within the application areas.

Public perceptions of the SWASS program effects and perceived changes to the quality of the environmental-social settings were gleaned from comments received from people contacted during the evaluations for the aforementioned areas of concern. A collection of communications compiled by Dr. Jack Pitcher, formerly Veterinarian in Charge of the Douglas, Arizona Screwworm Laboratory, was extremely helpful in determining the perceived changes or effects on the environmental-social setting.

Sections 7.1 and 7.2 of this report set forth the difficulties encountered and the results of the evaluations for government program conflicts and perceived changes to the environmental-social settings.

7.1 Program Conflicts

The Program Conflict portion of the EEP methodology is used to evaluate the negative effects of pesticide programs on govern-

ment experimental and conservation programs in which Federal and state governments participate. The government programs investigated are of two general types:

- pure research, and
- applied research, such as resource management programs.

Both of these types of programs were identified in the designated assessment areas and investigated. The following sections outline the sources of information and responses received from respondents for each program location.

7.1.1 Identification of Government Programs

Potentially affectable government programs were identified using:

- the ARS Western Region Directory (USDA, 1977),
- the ARS Southern Region Research Directory (USDA, 1977),
- the Professional Workers in State Agriculture Experiment Stations and Other Cooperating State Institutions/1978 - 79 Directory (USDA, 1979), and
- the National Wildlife Federation Conservation Directory 1980 (National Wildlife Federation, 1980).

Two criteria for inclusion were established from which programs to be investigated were identified. The first was that the program be conducted in or near the study regions 1, 2, or 3 in Arizona, New Mexico, and Texas of the SWASS environmental evaluation. The second was that the programs involve insect, aquatic, or wildlife studies which could possibly be affected.

The research centers identified and investigated were:

- USDA/ARS Subtropical Texas Stations of Brownsville, Mission, and Weslaco, Texas;
- Texas A&M University Departments of Animal Science, Entomology, Range Science, Veterinary Microbiology and Parasitology, and Wildlife and Fisheries Science;
- Texas State Entomologist;
- Texas Research Centers at Corpus Christi, El Paso, San Angelo, Uvalde, and Weslaco;
- Flagstaff Arizona - Rocky Mt. Forest and Range Experiment Station, Phoenix Cotton Research Center and Bee Research Laboratory;
- University of Arizona Departments of Animal Sciences, Entomology, Renewable Natural Resources, and Veterinary Medicine;
- Arizona Cooperative Fishery Research Unit and Arizona Cooperative Wildlife Research Unit; and
- New Mexico State University Departments of Animal and Range Sciences, Entomology and Plant Pathology, Fishery and Wildlife Sciences, and Southeastern Branch Stations of Middle Rio Grande.

Responsible personnel for each program were contacted by telephone and questioned.

7.1.3 Results and Conclusions

It is highly unlikely that any program would be affected by SWASS, but since it is known that there are effects on non-target Diptera (Calliphoridae, Sarcophagidae, Anthomyiidae, and Muscidae), and because researchers might be concerned with potential effects on aquatic and terrestrial organisms, ongoing research projects in these areas were investigated.

In all, thirty responses were collected. No negative effects were attributed to the SWASS program with regard to government program conflicts by any of the program personnel questioned. However, three respondents did cite possible indirect

effects due to a decline in size of screwworm fly populations and therefore subsequent subtle changes in the populations of fauna involved in their studies. These three respondents however could not attribute the effects to the specific use of SWASS. Their responses were only in response to a general decline in screwworm fly populations.

It was clear from the conversations with the program personnel that most people do not distinguish between the effects of SWASS and the sterile fly release program.

7.2 Impacts on the Environmental-Social Settings

Three major areas of consideration for the effects on the environmental-social settings are discernible. The areas are the most obvious aspects of the human environment, namely, physical surroundings, water, and perceived well-being. It is in these three areas that the SWASS program was investigated using information collected in regard to the evaluations of the previous chapters.

The section using information at hand, analyzes the perceived changes to the environmental-social setting as indicated by perceived effects on the physical surroundings, water, and personal well-being brought about by the use of SWASS.

7.2.1 Physical Surroundings

The small dark colored pellet form of SWASS makes it difficult to detect in nature. This feature of the program is enhanced by the light distribution of application with a rate of approximately one pellet per 4.3 acres over sparsely populated area rangelands. The swormlure-2 component does however emit an offensive odor which may make the pellet odoriferously detectable to humans passing near the pellet. Overall, the pellet probably produces little or no negative effects on the physical surroundings perceivable to the general public, especially since the

pellets are not applied on National Park Service lands and only with discretion on U. S. Forest Service and Bureau of Land Management lands where the public would be using sparsely populated areas for recreation.

7.2.2 Water

SWASS pellets are applied aerially with certain precautionary guidelines, one such guideline being that the pellets are not dropped within $\frac{1}{2}$ mile of any stream, estuary, lake, or other body of water. This precaution is taken to avoid possible contamination of water supplies and aquatic habitats. The probability of at least one pellet being mistakenly dropped in a pond assuming uniform distribution of pellets has been calculated to be 0.21 during a two-week treatment period for a $\frac{1}{4}$ acre cattle tank. Cattle tanks are the smallest commonly found body of water in the study areas and are used in most of the following examples because one pellet would probably produce the highest concentration of SWASS chemical components achievable in any body of water. Moreover, those persons applying SWASS aerially feel cattle tanks are the most difficult to avoid when dropping SWASS because it is very difficult to cut off the dropping mechanisms to avoid such a small area without losing many acres of ground coverage.

The initial concentration of toxicant from one pellet dropped in a $\frac{1}{4}$ acre, three feet deep cattle tank as noted in Section 3.3.2 would be 60 mg/943,000 liters or 0.00006 ppm, a concentration of toxicant well below concentrations considered to be toxic to most aquatic organisms. The maximum concentration expected is less than .0001 ppm.

The phenol and p-cresol components of the swormlure can impart objectionable odors in very small concentrations to water. Threshold concentrations imparting objectionable odors for phenol and p-cresol are 1 to 4 ppm and 0.055 ppm, respective-

ly (in Buikema et al., 1979). The initial concentration of phenol and p-cresol for the aforescribed cattle tank in which one pellet is dropped would be approximately 0.00009 ppm, a concentration well below the threshold known to impart objectionable odor to water. The threshold concentration of phenol in water which may cause tainting of the flesh of fish has been determined to be between 1 and 10 ppm (in National Academy of Sciences, 1973). Since these chemicals are degraded by aquatic microorganisms, the phenol and p-cresol concentration in a cattle tank, even with successive inadvertent misapplications, would be negligible and would not taint fish flesh or impart objectionable odor to the water.

Other than inadvertent application of pellets into a body of water, another possible method of introduction of SWASS chemicals is runoff. However, as demonstrated in Section 3.3.1, negligible quantities of the SWASS pellet chemicals would be expected to enter a waterway since most would be sorbed by the soil, degraded, or greatly diluted before reaching a body of water at least $\frac{1}{2}$ mile away. This portal of entry is not considered further in this section because of the remote possibility of effect on the waters.

7.2.3 Perceived Well-Being of Inhabitants in Application Areas

The inhabitants of the SWASS application areas may experience a more positive sense of well-being because:

- the SWASS treatment program uses pellets rather than sprays which many people feel are more harmful,
- sterile fly releases may cause anxiety with the general public because of the increase in observable fly populations, and
- the size of the screwworm fly population decreases significantly with the SWASS applications giving a sense of relief from possible infections.

Overall, the SWASS program may indirectly elevate the general public's sense of well-being.

7.3 Summary

- No direct research program conflicts were identified during the telephone investigations.
- It was clear from conversations with program personnel that most people do not distinguish between the effects of SWASS and the sterile fly release program.
- The SWASS pellets should not create any perceivable change in the physical surroundings of the general public.
- The accidental application of SWASS would not cause perceivable impacts on the aquatic environment, water quality, or aquatic organisms.
- The SWASS treatment programs may be perceived to be more acceptable than the sterile fly release program because it would decrease the number of flies immediately whereas the sterile fly release program initially increases the number of flies by adding the sterile males to the wild screwworm fly populations. General well-being may be perceived to be increased because there are fewer flies immediately.

CHAPTER 8

CONCLUSIONS TO THE ENVIRONMENTAL EVALUATION

8.0 Introduction

The first portion of the impact assessment of the SWASS program has been the evaluation of the environmental effects of the use of SWASS in the southwestern United States. If the SWASS program in Mexico is subject to the requirements of Executive Order 12114, "Environmental Effects Abroad of Major Federal Actions", the Veterinary Services must perform an environmental study of the program. In order to facilitate the application of the results of this study to an assessment for Mexico, three regions in the southwestern United States were chosen which were representative of areas in northern Mexico where SWASS would be used early in the screwworm eradication program. This study, then, was an environmental assessment of the SWASS program as it would be conducted in these three representative regions.

There are no pre-determined treatment areas as such in the SWASS program. SWASS is applied in response to a significant number of reported screwworm cases in an area or a significant number of wild flies caught in traps. Thus, it is not known at the beginning of a season where or when SWASS will be required. For the purposes of this assessment it was assumed that SWASS might be applied anywhere within any of the three representative regions.

The principal analyses in this assessment were as follows:

- determination of the environmental fate and behavior of the SWASS chemicals,
- risk assessments in three major areas of concern - aquatic organisms, terrestrial organisms, and humans, and

- an assessment of program conflicts and other environmental-social effects of the SWASS program.

Conclusions from these analyses are presented in the following sections.

8.1 Environmental Fate and Behavior

The chemicals in SWASS are short-lived in the environment. The chemical attractant in the SWASS pellet, known as swormlure-2, is composed of naturally-occurring compounds of simple structure. The insecticide dichlorvos (DDVP) hydrolyzes rapidly in air and in waters of the Southwest, and all of the SWASS chemicals are actively degraded by microorganisms in soil and water.

The application of SWASS is prohibited within $\frac{1}{2}$ mile of lakes, streams, estuaries, or other bodies of water, and the concentration of SWASS chemicals in these waters will be negligible. The most likely route for the transport of SWASS chemicals into aquatic systems is the inadvertent and often unavoidable application of pellets to small ponds and livestock tanks. The probability that a pond or tank will receive a pellet during the aerial application of SWASS is small, about 0.21 (one chance in five) for a $\frac{1}{4}$ acre pond during a two week treatment program. Even with successive inadvertent applications to a small pond, the concentration of SWASS chemicals in the water would be very small, probably less than 0.1 part per billion for DDVP.

8.2 Effects on Aquatic Organisms

The principal hazard to aquatic organisms from SWASS pellets is the acute toxicity of insecticide component, DDVP. This compound is toxic to fish and very toxic to aquatic arthropods. However, the small amount of toxicant in the pellets, the wide dispersion of the pellets, and the restrictions on application of pellets near waterways are such that the concentration of DDVP in natural waters will be very small. Concentrations will be orders

of magnitude less than the LC_{50} 's (median lethal concentrations) for fish, mollusks, and economically important crustaceans. In fact, the only potential effect might be the mortality of some daphnids (water fleas), minute crustacean zooplankton which are extremely sensitive to DDVP. Although zooplankton are very important in aquatic food webs, other zooplankton are much more resistant to DDVP, and the use of SWASS is expected to have no effect on aquatic ecosystems.

No residues of DDVP are expected in any fish or fisheries products, and residues of swormlure chemicals in fisheries products from lakes, streams, and estuaries will be negligible. Even with successive inadvertent application of SWASS pellets to fish ponds, residues of the most toxic swormlure chemicals (phenol and p-cresol) will still be less than 1 part per billion. Swormlure residues are transient in aquatic organisms.

When applied in accordance with its restrictions, SWASS will have no effect on endangered and threatened aquatic species.

8.3 Effects on Terrestrial Organisms

Some soil organisms might be killed during SWASS treatments, but only in the immediate vicinity of the pellets. Because of the wide dispersion of the pellets, these effects will be insignificant. There will be some mortality of non-target insects. Field studies indicate that almost all of the non-target mortality is concentrated in four families of flies, many of which are considered pest species. Effects on populations of these species should be short-term. Bees are not expected to be affected by SWASS applications. Populations of non-target insects should not be significantly affected by SWASS; thus, no indirect effects are expected on insectivorous species of wildlife.

DDVP has a high acute toxicity to birds and many species of mammals, and one SWASS pellet contains an acute lethal dose of that compound for the smaller species. The determination of risk

to a member of a species entails knowing whether or not it would ingest a SWASS pellet, but at the present time the attractiveness of SWASS pellets to wildlife is not well known. The species most at risk appear to be small scavenging rodents such as cotton rats and wood rats, although no mortality of wildlife from SWASS pellets has been observed in pen tests or field studies. Any mortality would probably be an isolated occurrence, and populations would not be affected.

Scavenging carnivores and omnivores might be attracted to SWASS pellets, but their size and relative resistance to DDVP are such that ingestion of a pellet would probably not be lethal. No effects are expected on livestock, grazing wildlife, birds, or reptiles.

No residues of SWASS or swormlure are expected in the meat of cattle, sheep, goats, grazing wildlife, poultry, or game birds, or in milk and eggs. There is the possibility that pigs, javelinas, and rabbits might eat a SWASS pellet, but residues in the meat of these species will be negligible.

The use of SWASS should have no effects on members of terrestrial endangered or threatened species.

8.4 Effects on Humans

Concentrations of SWASS chemicals in the air will be negligible as will residues in food and water. The only way in which a human might encounter significant quantities of SWASS chemicals would be in eating a pellet. The pellets are applied in sparsely populated areas and the odor is very disagreeable, so it is doubtful that a pellet would be encountered, let alone eaten. The amount of toxicant in a pellet is very small relative to the size of a human, so that even if a child were to eat a whole pellet it is doubtful that any toxic symptoms would be observed. Thus, the risk to humans from the use of SWASS appears negligible.

8.5 Program Conflicts and Other Environmental - Social Effects

The SWASS treatment program was not directly shown to conflict with any of the investigated government programs in the study areas. It became clear during the investigation of program conflicts that very few people were able to distinguish between the effects of sterile fly release and SWASS treatments.

The final evaluation of the SWASS environmental evaluation sought to identify impacts on the perceived quality of life for inhabitants of the SWASS application areas. The physical surroundings, water and perceived well-being were seen as areas in which the perceived quality of life could possibly be affected. However, no direct impacts were discerned in any of these areas under probable application conditions. Possible positive effects may include an elevated sense of well-being with the rapid decrease in screwworm fly populations.

CHAPTER 9
ECONOMIC ANALYSIS OF SWASS - INTRODUCTION
AND SMALL AREA ANALYSIS

9.0 Introduction to the Economic Analysis of SWASS

The fundamental premise of the sterile male technique is to overwhelm the native fly population with sterile male flies. If this basic premise is not satisfied, the sterile male technique will not work. Enough competitive sterile male flies must be dropped to effectively compete with the native males and to fight the growth of the native population. In the past, the use of sterile males has been successful in eradicating the screwworm fly in most areas. In some small areas, however, control of the native fly has not been obtained. Several times, due to this lack of control, large infestations have resulted from the spread of flies from these uncontrolled areas. Many reasons have been given for these failures, including:

- uncompetitive fly strains,
- insufficient available sterile flies,
- extremely rapid growth of wild fly populations caused by ideal weather conditions, and
- dense initial wild fly populations.

Regardless of the reason for failure, substantially more flies would have been needed to overwhelm the native populations. In all likelihood, the number of flies that would have been necessary to control the native population could not feasibly be dropped. For these special situations, assistance is needed for the sterile flies. The wild populations must be reduced to a level that can be handled with reasonable applications of sterile flies. SWASS is intended to be the needed help.

The economic analysis is conducted on two levels: small area and large area. The small area analysis considers individual applications of sterile flies and SWASS and is done on one square mile areas. The large area analysis looks at SWASS as a supplement to the sterile fly program. It considers the long-term effect on the movement of the sterile fly barrier as a result of using SWASS. The small area analysis follows in this chapter. The large area analysis is presented in the next chapter.

9.1 Introduction to the Small Area Analysis

The economic effectiveness of SWASS usage in small areas is examined in this section. Information presented in this section could prove to be especially valuable in the near future with movement of the screwworm eradication program further into Mexico. The climate in parts of Mexico is generally more suitable for the screwworm fly than that of the southwestern United States. As a result, more frequent incidences of dense screwworm fly populations and high growth rates can be expected. SWASS was developed as a tool for these occasions to knock down the population to a level that would allow the sterile males to be effective.

The small area analysis discusses the economics and feasibility from four perspectives:

- 1) the change in native female populations from one generation to the next with varying numbers of competitive sterile males (fly competitiveness times the number of sterile males released; see Section 9.2), with and without SWASS,
- 2) the comparison of the costs of sterile male programs and SWASS/sterile male programs that result in equal reductions of the native populations,
- 3) the comparison of the effectiveness of sterile male programs and SWASS/sterile male programs that have equal costs, and

- 4) the possibility of using multiple strains to combat the screwworm fly problem.

9.2 Population Dynamics

The effectiveness of various sterile male and SWASS/sterile male programs was evaluated using a modified version of Knippling's formula (Peterson, 1977) which has been adjusted to consider the effects of both SWASS and sterile males. The formula is:

$$N_{i+1} = g_i \frac{((1-f)N_i)^2}{(1-f)N_i + e(1-m)S_i}, \text{ where} \quad (1)$$

N_{i+1} = number of native females per square mile for the $(i+1)^{\text{st}}$ generation,

N_i = number of native females per square mile for the i^{th} generation,

S_i = number of sterile males released per square mile per application during the i^{th} generation,

g_i = growth rate for i^{th} generation,

f = SWASS effectiveness on female flies (percentage of female flies killed by SWASS),

m = SWASS effectiveness on male flies (percentage of male flies killed by SWASS), and

e = competitive factor for sterile male flies (ratio of native flies to sterile flies to obtain 50% sterility of egg masses).

An explanation of this equation is given in Appendix D.

After polling screwworm experts, point estimates and range estimates have been determined for the parameters in the above equation. The maximum number of native females per square mile (N_i and N_{i+1}) is one hundred (Knippling, 1980, Bushland, 1980). For the purposes of this study, we will consider a range of zero to two hundred females per square mile. This will allow for the possibility that outbreak conditions in southern Mexico are worse than in the southwestern United States. Since a "standard" application of sterile flies is two thousand flies per square mile, the "standard" application of sterile males (S_i) is one thousand sterile males per square mile. However there have been instances where up to sixteen thousand flies per square mile have been applied. Hence, we will consider S_i to range from zero to eight thousand sterile males per square mile. S_i refers to the number of sterile males applied per square mile for each application.

Normally the highest population growth rate (g_i) is 5X, however it could be as high as 10X (Knippling, 1980) or 20X (Hoffman, 1979). We will consider a range for g_i from 1X to 20X. SWASS effectiveness on female flies (f) has been estimated between .65 and .90, however we will use the estimate .80 (Coppedge, 1979). SWASS effectiveness on male flies (m) is estimated to be one-fourth the effectiveness on female flies or .20 (Coppedge, 1979). The competitive factor for sterile male flies (e) is at most 0.125, and could be less than 0.01 in certain circumstances (Beal, 1980).

9.3 Effectiveness of Sterile Male and SWASS/Sterile Male Programs

In order to demonstrate the relative effectiveness of sterile male and SWASS/sterile male programs, Table B.1 and Figure B.1 have been prepared and can be found in Appendix B. Table B.1 lists the number of native females in the $(i+1)$ st generation assuming a variety of population parameters for the I^{th} generation

in equation (1). Figures B.1 - B.5 compares sterile male and SWASS/sterile male programs, again using equation (1), by showing the number of competitive sterile males needed to achieve different levels of effectiveness against a given native population. For Figures B.1 - B.5, three levels of effectiveness were chosen; control, which is a minimum level of effectiveness at which no reduction takes place; 50% reduction, which is a mid range value of reduction; and 90% reduction, which demonstrates the number of required flies necessary for almost total extermination of the native flies in one generation.

In order to calculate from Figure B.1 the assumed drop rate, one must multiply by two the number of necessary competitive males divided by the assumed competitive factor. Using this method a fly drop of 2,000 would be equivalent to 125 competitive males if the competitiveness factor were 0.125.

One must note that in Table B.1, the $(i+1)$ st generations of flies achieve densities of native females greater than 100 per square mile, which is probably not feasible. These numbers were derived from the population formulas and should be used to indicate population pressure and migration. If there are 500 native flies per square mile indicated in the $(i+1)$ st generation, those 500 flies will probably not all be in the original square mile, but they will exist somewhere in the environs.

Under the given assumptions, as can be seen in Table B.1 and Figures B.1 - B.5, sterile fly releases are far less effective than SWASS/sterile male programs with the same number of sterile males. However, since costs are not considered in these examples this does not provide any final conclusions.

Of more importance is the ability to control and knock down the native population with a practical number of flies. The following conclusions are based on Table B.1 and Figures B.1 - B.5, assuming a competitiveness factor no greater than 0.125.

- Under conditions where the growth rate is 1X, sterile fly releases should be able to effectively control and reduce native populations.
- With a growth rate of 3X, at least 8,000 sterile flies would be required to achieve a 50% reduction in a native fly population with 100 females.
- It would require at least 3,000 sterile flies to control a native population of 100 females.
- The standard drop rate of 2,000 flies would possibly only control a population of 65 native females per square mile.
- Standard applications of SWASS and sterile flies are able to significantly reduce populations with growth rates up to 3X.
- For a growth rate of 5X the standard application of 2,000 sterile flies per square mile would not control native populations greater than thirty females per square mile.
- For a large population of native flies, with a growth rate of 5X, neither standard nor practical size drops of sterile flies would achieve control or reduction of the native fly population.
- Standard applications of sterile males and SWASS should result in reduction of the same native populations with growth rate of 5X.
- For a growth rate of 10X, it is almost impossible to control many native populations with any practical level of sterile flies alone. Over 10,000 sterile flies would be needed to control 100 native females per square mile with a growth rate of 10X.
- The combination of a standard application of SWASS and sterile flies could still be used to control populations with a growth rate of 10X.

- If the growth rate reaches 20X, it would be impossible to control the native populations with any feasible number of sterile flies alone.
- The combination of SWASS and 2,000 sterile flies may achieve a control over the growth of such a population with more sterile flies being required to achieve reduction of native population.

This analysis vividly indicates the potential need for the availability of a system such as SWASS to supplement the use of sterile flies. As is indicated in Table B.1 and Figure B.1, the number of effective, competitive sterile males needed to control or reduce native fly populations when used alone is several times larger than the number required when sterile flies and SWASS are used together. For the smaller or low growth rate populations, a standard application of 2,000 sterile flies will control and reduce populations. For the instances when the native fly population is sufficiently large and fast growing, no practical number of sterile flies with the present levels of effectiveness will be able to adequately control native populations without the supplemental use of SWASS or other aide. Furthermore, even if a practical means of dropping large quantities of sterile flies alone (20,000+ per square mile) were developed, it would still be more cost effective to consider the use of SWASS and sterile flies together. This will be shown in the next section.

9.4 Costs for Equally Effective Programs

Since complete cost figures could not be obtained for the Tuxtla Gutierrez facility, the cost figures for this report will be based on those of the Mission facility. Fly cost per thousand was \$1.35 in 1978 (Fossum, 1980). The portion of this cost that was attributable to distribution was \$0.56. The present cost for SWASS production is \$1.01 per pound. During the second half of FY 1979, the distribution costs of SWASS were estimated at \$2.51 per hour. In late 1979, 13,979 pounds of SWASS was distributed from

the Mission facility in 163 hours. This yields an estimated cost of \$2.93 per square mile to distribute SWASS (Fossum, 1980).

Distribution costs increased at a rate of twelve percent in 1979. We will assume that distribution costs are increasing at a rate of fifteen percent in 1980. Also, we will assume that all other costs increase at a rate of ten percent per year. These inflation rates yield the following cost estimates for 1980: \$1.68 per thousand flies per square mile and \$3.94 per square mile to apply SWASS.

Assuming these rates, a standard application of SWASS, twice each week for three weeks at a rate of one pound per square mile per application, would cost \$23.64. Applications of sterile flies at a rate of two thousand flies per square mile each week for three weeks would cost \$10.08 per square mile.

These costs are used throughout the small area analysis.

Table B.2 gives a comparison of costs of programs using SWASS and sterile flies and programs using sterile flies alone. It was assumed that one pound per square mile twice a week of SWASS would be a standard application of SWASS for the three weeks per generation. These costs of SWASS per generation were estimated at \$23.64. Sterile flies were assumed to cost \$1.68 a thousand. A drop of given flies in this case is assumed to be the given number of flies dropped each week for the three weeks of the generation life cycle and would then cost \$5.04 per thousand per generation.

As can be seen in Table B.3, depending upon the competitiveness of the sterile flies, if there are as few as ten to twenty-five native females per square mile, it would cost more to use sterile flies to achieve the same effectiveness as a SWASS/sterile fly program.

Although the SWASS/sterile fly program is more cost effective even at rather low populations, it may not be practical to try to use SWASS at such low population levels. There are several reasons for this:

- there is a limit in the amount of SWASS available,
- the difference in the theoretical amount of reduction is insignificant (with twenty-five native females per square mile and a competitiveness of .125, there would be 4.2 native females in the next generation without SWASS and .2 with/if SWASS were used), and
- the inexactness of the model, the lack of the ability to determine the sizes of a native population, and the ability of sterile flies alone to reduce the native fly population in such cases makes it unwise to try to apply the results of the model with a close tolerance.

In summary, data presented in Table B.2 shows the use of SWASS/sterile male programs to be cost effective even where relatively small populations of native flies exist. However, in actual operations, the decision-maker must consider the availability of SWASS, the availability of sterile flies, the uncertainty level of the native fly population and amount of reduction which can be achieved with flies alone before applying SWASS. Certainly in cases of high native fly populations there will be little choice but to use SWASS and sterile flies however, in cases of lesser infestations, the cost effective use of SWASS must be determined on a case by case basis.

9.5 Effectiveness of Programs of Equal Costs

If the chart labeled Table B.3 in Appendix B is analyzed, SWASS/sterile male programs appear to be more effective than sterile male programs of equal cost. However, if the growth rate is low, sterile flies could take as few as one generation longer

to eradicate the native population. Since it is difficult to determine when an area is screwworm free, it is plausible that flies would be dropped for the same number of generations with both programs, resulting in no real savings.

The important factor to consider is what sort of reduction in fly population is desired. Can the sterile male program or the SWASS/sterile male program achieve this rate of reduction? If both types of programs can achieve the desired rate of reduction, is there a significant difference in the time that it takes to eradicate the native population? This question must be answered on a case by case basis using the best information available.

9.6 Multiple Strains

The question of the use of multiple strains has arisen. Would the use of multiple strains be cost effective and would it affect the decision that SWASS is a necessary tool in the fight against screwworms?

Presently there appears to be much disagreement about the use of multiple strains and their cost and effectiveness.

One approach suggested would be to employ four strains at Tuxtla and two strains at Mission. It is also recommended that up to three colonies be bred at Mission and six colonies at Tuxtla. The advantage of this system would be that there could be a rapid shift in fly strains. The various strains would be released in areas where similar strains are believed to exist. It is estimated that costs would be one third more than the present single strain techniques. However, it may be possible to achieve competitive ratios four times as high as with single strains (Beal, 1980). If the estimates of cost and effectiveness for this technique are valid, there would be no question that it would be useful.

Another possibility suggested would be to employ three strains of flies and release them in all regions of screwworm eradication. There should be no significant increase in operational costs for this technique, but the fixed expense for modifying the Tuxtla plant to handle multiple strains would be about \$3,000,000 (Hoffman, 1980). It is estimated that these flies would be three times as effective as the single strains (Knippling, 1980).

Questions still exist about the potential costs and effectiveness of multiple strain techniques. It is the opinion of many that the exact benefit of multiple strains is still unknown, although many experts feel there should be some benefits gained from their usage (Whitten, 1980). Because of these uncertainties it is unclear how the introduction of multiple strains would affect the relative merits and cost effectiveness of SWASS/sterile male programs versus sterile male only programs.

However, from the present analysis it appears that since SWASS/sterile male programs appear to be absolutely necessary in cases of very heavy infestation or high growth rates and probably are cost effective for many cases of moderate infestation, SWASS/sterile male programs will still be cost effective in many cases of heavy infestation even if multiple strains improve sterile male competitiveness.

9.7 Conclusions

After a thorough analysis of SWASS and the screwworm population dynamics model, we have concluded that SWASS is a cost effective addition to the sterile fly to control small area native populations with large populations or high growth rates. Furthermore, we feel that SWASS may be the only practical means presently available of controlling some few intense small area outbreaks unless extraordinarily high numbers of sterile flies would be feasible on a per square mile basis.

It also appears that for most moderate or even some small populations of native flies the use of SWASS is theoretically cost effective. However, the use of SWASS in such cases might not be practical because of the overall supply of SWASS, the difficulties of determining native populations, the lack of significant differences in costs and effectiveness between SWASS/sterile male programs and sterile male alone programs needed for such native population levels, and because of potential for increased administrative burden which would arise if decisions concerning SWASS usage for multitudes of small areas had to be made and carried out in daily operations.

It is recommended that, as planned, relatively simple procedures for determining SWASS usage be developed which could be easily administered and which would guarantee that SWASS be used in the important heavy infestations. In such uses SWASS is necessary and certain to be cost effective. In this way, SWASS could be used to support the orderly movement of the sterile fly barrier to its planned new position.

CHAPTER 10
ECONOMIC ANALYSIS OF SWASS AS A SUPPLEMENT
TO THE CURRENT STERILE FLY PROGRAM

10.0 Background

Presently, the sterile fly barrier, maintained to prevent screwworm infestation in the United States, stretches across a large expanse in northern Mexico south of the United States-Mexico border. Estimates of cost benefit ratios to the United States of this program have ranged from approximately 1:10 to as high as 1:113 (Prater and Goodman in Scruggs, 1975). Maintaining this barrier along the approximately 2000 mile border is expensive and difficult. Some outbreaks of infestation occur in the United States from time to time causing economic damage, mainly to the livestock industry. Because of these problems, the United States and Mexico are currently working on a program to eradicate the screwworm fly in northern Mexico and in so doing, move the barrier to the narrow Isthmus of Tehuantepec in southern Mexico. Such an action could further increase the long term benefits of the program by significantly reducing infestations in Mexico, by virtually eliminating outbreaks within the southwestern United States, and by significantly reducing operational costs due to the large reduction in the size of the barrier that would be maintained. Thus, the United States would benefit economically due to the reduced costs of operations and the further reduction of economic damage caused by screwworm infestation in the southwestern United States.

It is believed that SWASS, used as a supplement to the sterile male program in areas of high wild fly growth or dense populations, would be extremely beneficial in the eradication of wild flies in northern Mexico and the subsequent southward movement of

the sterile fly barrier. It is felt that this supplement would make the eradication program more effective in such areas and by doing so, quicken the pace of barrier movement southward. This could lead to savings in long term operational expenses for the United States due to the earlier establishment of the less expensive barrier at the Isthmus of Tehuantepec. It would also help to reduce more quickly the economic losses from the remaining outbreaks which occur in the United States.

Since SWASS is an addition to the base program during the barrier movement, it is necessary to ascertain if the potential savings will outweigh the added expense of using SWASS. In order to do this the costs and additional benefits gained by the SWASS/sterile male program must be compared to the costs and any additional benefits accrued by the movement of the barrier without SWASS. Since the value of the basic program of barrier maintenance has been established, only the marginal differences in the above two programs must be considered to determine if the benefits of SWASS usage outweigh the costs.

In order to examine this issue, several steps must be taken.

- The operational plans must be compared and their operational parameters must be determined.
- The potential operating characteristics and subsequent operational costs must be estimated for each operational plan.
- Other costs and savings associated with each plan must be estimated.
- A valuation of the present value of the costs and benefits of each plan must be calculated and a final comparison of the results made.

Once these steps are finished, conclusions can be drawn.

The operational plans to be compared and the methodology to be used are discussed in the following sections.

10.1 Description of Competing Operational Plans

Two basic operational approaches to the eradication of the screwworm fly in northern Mexico and movement of the sterile fly barrier to the Isthmus of Tehuantepec will be considered. The first uses sterile flies alone. Each production facility will produce a strain of flies, and the strains at each of the two facilities will differ. Total combined production of approximately 500 million flies a week will be assumed, 300 million at the Tuxtla Gutierrez, Chiapas, Mexico facility and 200 million at the Mission, Texas facility. The program will be assumed to have the largely responsive pattern of operation presently used; that is, a response to outbreaks and to the general pattern of fly population as determined by such factors as weather, terrain, and potential hosts. Further, it will be assumed that full scale operations will continue in this fashion until the barrier movement is complete. At that time operations will be reduced to the level needed to maintain the new, smaller barrier.

The second approach to be considered assumes SWASS is added to the first program. It is assumed that SWASS will be used in a limited number of smaller areas as an aid to sterile flies where eradication is difficult. The pattern of cases and fly population which will prompt the use of SWASS is now being defined by the Joint Mexico-America Committee. It is assumed that operational procedures used in the actual application of SWASS will be similar to the present patterns established during the experimental stages, i.e., similar drop patterns, swath widths, poundage per square mile, and size of application areas surrounding reported cases.

10.2 Potential Operational Characteristics and Estimated Operating Costs

It is assumed that 500 million flies will be released each week until the barrier is in place at the Isthmus of Tehuantepec.

When the barrier is in place, the number of flies released will drop to between 100 and 140 million flies per week. The cost of dropping flies at the present rate is about \$43.7 million. The cost of maintaining the barrier at the Isthmus of Tehuantepec is estimated to be \$10.5 million in 1980 dollars.

We estimate that the program using SWASS will use 500,000 pounds of SWASS per year (Judy, 1980). This would mean an additional cost of \$2.0 million or a total of \$45.7 million per year using SWASS and sterile flies in the program.

The portion of these costs that is the responsibility of the United States is 80 percent. This means that the sterile male program would cost the United States \$35.0 million per year and the SWASS/sterile male program \$36.6 million per year until the barrier is established at the Isthmus of Tehuantepec. Once the barrier is established, the cost to the United States will be \$8.4 million per year.

In order to assess the effectiveness of SWASS as a part of the barrier movement, we will assume a discount rate of ten percent in our comparison of program costs.

The general consensus of the professional in the screwworm program is that the barrier can be moved to the isthmus in the next three to six years if SWASS is used. It is also believed that without SWASS it will take at least one additional year. Most of the people with whom the problem was discussed feel that it could take many more years to complete the barrier movement without SWASS.

10.3 Comparison of Potential Costs

Under these cost assumptions we will analyze the discounted costs of the barrier movement using the SWASS/sterile male program versus sterile males alone program. In these calculations of costs to the United States, operational costs only will be

considered. It is felt that each program has already achieved control of screwworms in the United States so that no differences in savings arise from elimination of cases in the United States. Only 1 reported case has occurred in 1980 in the United States. However, since the cost per case was considered in the process of this analysis, Appendix B presents a present estimate of the cost per case of screwworm infestation in the United States. As can be seen, the cost is substantial and the complete elimination of the barrier program and the ensuing return of hundreds of thousands of screwworm cases in the United States could be extremely costly.

In order to calculate the present value of either program in operating costs for n years, $PV(n)$, we must evaluate the formula:

$$PV(n) = \sum_{k=1}^n C_k \cdot V^k \quad \text{where}$$

C_k is the program cost for the kth year and
 $V = 1/1.1$

For the program using SWASS, $C_k = \$36.6$ million for $k \leq t$ where t is the number of years required to put the barrier in place, and $C_k = \$8.4$ for $k > t$.

For the program without SWASS, $C_k = \$35.0$ million for $k \leq s$ where s is the number of years to place the barrier without SWASS and $C_k = \$8.4$ million for $k > s$.

Using the given equation and the assumed values the discounted U. S. costs in millions of the program using SWASS is assuming t years in:

$$PV_{sw}(t) = \$ \left[\sum_{k=1}^t 36.6 \cdot V^k + \sum_{k=t+1}^{\infty} 8.4 \cdot V^k \right]$$

The discounted U. S. costs in millions of the program without SWASS assuming s years to place the barrier by this method is:

$$PV_f(s) = \$ \left[\sum_{k=1}^s 35.0 V^k + \sum_{k=s+1}^{\infty} 8.4 V^k \right]$$

The difference of the discounted value of the costs of the two programs for any pair of values t and s, s > t is:

$$PV_f(s) - PV_{sw}(t) = \$ \left[\sum_{k=1}^t -1.6 V^k + \sum_{k=t+1}^s 26.6 V^k \right]$$

As can be seen from the formula the smallest difference in the cost of the two programs for a given value of t would be if s = t + 1, i.e., if it took only one more year longer to move the barrier without SWASS than it took to move it with SWASS.

Table 10.1 gives comparative discounted costs and cost differentials for various time assumptions over an eleven year time period. The table gives an assumed number of years for barrier movement with SWASS and sterile flies and assumes it will take only a single year more without SWASS.

TABLE 10-1
DISCOUNTED COSTS OF SELECTED PROGRAMS

YEARS	SWASS/STERILE FLIES	STERILE FLIES	DIFFERENTIAL
3	124.7	138.9	14.2
4	144.0	155.4	11.4
5	161.5	170.4	8.9
6	177.4	184.1	6.7
7	191.9	196.5	4.6
8	205.0	207.8	2.8
9	217.0	218.0	1.0
10	227.8	227.3	-0.5

As can be seen from the table, under this given assumption, only if it requires a minimum of 10 years to move the barrier using SWASS and 11 years without SWASS is the program without SWASS cost effective.

Thus even under the assumption of a minimum difference in programs, the SWASS aided program would have to take 10 years instead of the 3-6 years conjectured by the experts polled in order for SWASS not to be cost effective. Furthermore, SWASS becomes even more cost effective if the program without SWASS requires two or more years longer. For instance, if the SWASS program required 10 years and the program without SWASS should require 12 instead of 11 as assumed in the table, the cost differential would change from \$-0.7 million to approximately \$7.7 million less for the SWASS program.

For the normal estimates made by the experts polled there is little argument that SWASS would be cost effective. For instance, if the SWASS aided program were to require 5 years for barrier movement, and the sterile fly only program required 10 years, the respective discounted costs of the two programs for the 10 year time span would be \$158.5 million and \$215.1 million, a difference of over \$50 million in favor of SWASS.

10.4 Conclusions

Both the small area analysis and the general analysis of the barrier movement using SWASS provides overwhelming support for the cost effectiveness of SWASS usage.

In the case of small area infestations, using estimates of fly populations, growth rates and costs, we have shown that for cases of heavy infestation or growth rates, SWASS aided programs are the most cost effective and sometimes possibly the only methods available to control and reduce native populations. Furthermore, using the opinions of the many experts polled we conclude that SWASS used as planned could provide a significant reduction

in the time needed to move the barrier into place in southern Mexico and because of this reduction in time is likely to save the United States significant costs of program operations.

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APPENDIX A

HAZARD OF DDVP AND SWORMLURE TO
TERRESTRIAL ORGANISMS AND HUMANS

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HAZARD OF DDVP AND SWORMLURE TO
TERRESTRIAL ORGANISMS AND HUMANS

A.1 Hazard of DDVP to Terrestrial Organisms

The toxicant portion of SWASS is an organophosphorus compound 2,2-dichlorovinyl O,O-dimethyl phosphate (referred to as dichlorvos or DDVP in this report). Dichlorvos owes its insecticidal and acaricidal capacity to its ability to inhibit the activity of the cholinesterase (ChE) enzymes (Bibra, 1974), causing the accumulation of acetylcholine and resulting in overstimulation of the parasympathetic system and neuromuscular block. Wagner and Johnson (1970) theorized that acute deaths probably are due to weakness of respiratory muscles and obstructions of airways by bronchoconstriction and excessive secretions. Dichlorvos is effective as a fumigant, stomach, and contact poison (Thomson, 1977) and is not phytotoxic when used as directed on crops (Thomson, 1977 and Vevai, 1974).

Dichlorvos is rapidly metabolized and detoxified in the livers of mammals, a physiological characteristic which has been used to explain the negative results of in vivo mutagenicity tests and the low toxicity of DDVP to mammals (Bibra, 1974). Van Raalte (1970) noted significant differences between the amount of DDVP that causes intoxication in a single dose and the daily dose that causes poisoning "through continuous absorption for 24 hours per day from a slow release formulation".

Acute Toxicity. Table A-1 represents a compilation of acute toxicities for DDVP in terms of LD₅₀. Acute toxicities of DDVP vary within and among the tested animals for a number of reasons. Some reasons for variations are:

TABLE A-1
ACUTE TOXICITY OF DDVP TO TERRESTRIAL ORGANISMS

<u>SPECIES</u>	<u>EXPOSURE</u>	<u>LD₅₀ (mg/kg)</u>	<u>SOURCE</u>
MAMMALS			
Rat (male)	Oral	80	Durham et al. (1957)
(female)		56	
Rat	Subcutaneous	12	ITII (1976)
Rat (male)	Dermal	107	Durham et al. (1957)
(female)		75	
Mouse (male)	Oral	145	Wagner (1970)
(female)		135	
Mouse	Oral	124	Yamashita (1962)
Mouse	Oral	75 - 303	Ikeda (1958)
Mouse	Subcutaneous	24	Yamashita (1962)
Rabbit	Dermal	107	NIOSH (1979)
Dog	Oral	483	ITII (1976)
Dog	Oral	1090	NIOSH (1979)
BIRDS			
Chicken	Oral	15	NIOSH (1979)
Chicken	Subcutaneous	20	ITII (1976)
Quail	Unknown	1700	Vevai (1974)
Pheasant (young)	Oral	11.3	Tucker and Crabtree (1970)
Mallard (young)	Oral	7.8	Tucker and Crabtree (1970)
Duck	Oral	9.9	
Duck	Respiratory	4.7	
Wild bird	Oral	12	ITII (1976)
ARTHROPODS			
Housefly	Topical	0.6	Vevai (1974)
German Cockroach	Topical	4.0	Vevai (1974)

- size, age, and metabolism of organisms,
- method of exposure (oral, injection -- sub-cutaneous or intraperitoneal, inhalation, and dermal or topical), [NOTE: acute inhalation toxicity is higher than oral toxicity by a factor of at least 5 (Lofroth, 1970)], and
- dosage and grade of DDVP used.

The relationship between % deaths and oral doses of DDVP was established by Wagner and Johnson (1970) for adult male and female mice. Using a free hand regression line of the data, Wagner estimated graphically the LD₅₀ for mice at 145 mg/kg for males and 135 mg/kg for females. Figures A-1 and A-2 are representations of Wagner's % death and oral dose studies.

Sublethal Toxic Effects

Dichlorvos is the active ingredient in anthelmintic preparations for a variety of animals, as well as in dermally applied insecticidal sprays for horn flies (Haematobia irritans L.), face flies (Musca autumnalis), and stable flies (Stomoxys calcitrans L.) (Knapp and Graden, 1964). Control animals which have been successfully dewormed using DDVP are:

- primates,
- bears,
- camels,
- rodents, and
- reptiles (Hass et al., 1972).

Severe toxic symptoms have been noted when DDVP was administered in excessive doses. Bears in the Audubon Park Zoo were dosed with a DDVP anthelmintic preparation at a rate of 19 mg/lb or 41.8 mg/kg of estimated body weight (Clark et al., 1969). Of the twelve bears in the study three bears showed symptoms of clinical toxicosis. The bears reacting to these dosages were:

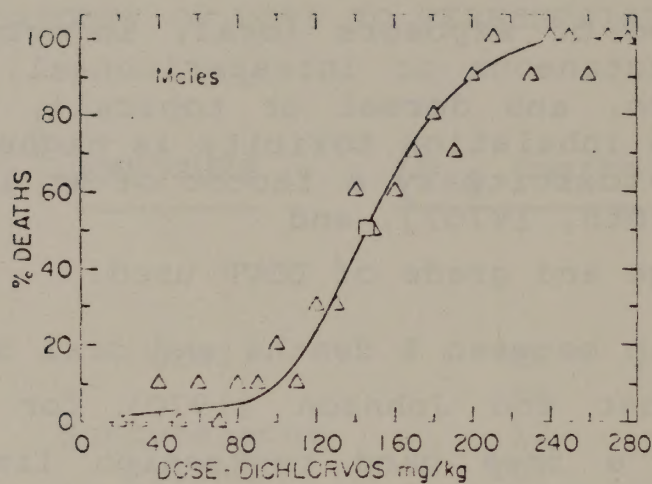


FIGURE A-1

% DEATHS AND ORAL DOSE OF DDVP FOR MALE MICE (WAGNER, 1970)

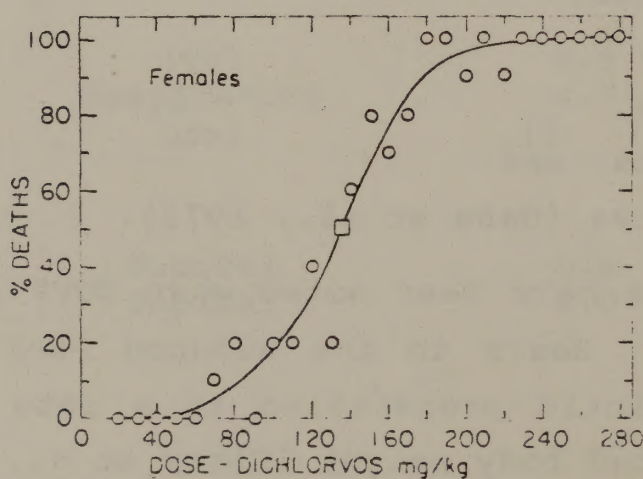


FIGURE A-2

% DEATHS AND ORAL DOSE OF DDVP FOR FEMALE MICE (WAGNER, 1970)

- a Kodiak bear, approximate weight 1300 lbs. - dosage 24.7g, and
- two polar bears, approximate weights 200 lbs. each - dosage 3.8g.

Dairy cows sprayed with an emulsifiable formulation of 44.5% DDVP were subjected to approximately 45 times the dose of DDVP normally used in controlling flies. Normal spray dose is 1% DDVP for two ounces of oil based spray per animal (Knapp and Graden, 1964). The emulsifiable formulation was more volatile than the usually used oil formulation causing the animals to inhale much more DDVP and solvent vapor. These cows experienced severe toxic symptoms of stress and/or convulsions. It was necessary to treat the animals with the antidote atropine sulfate. After the overdose, milk production decreased an average of 1.0 pound in the exposed Holsteins but gradually increased to the expected milk production by the third day. The Jersey milk cow's production decreased an average of 6.5 pounds and did not return to expected milk production until 18 days later.

Another study (Tracey et al., 1960) cited an incident in which a cow receiving a single oral dose of 27 mg DDVP/kg of body weight displayed symptoms of intoxication. Other studies on large oral doses found that 25 to 50 mg oral DDVP/kg are toxic to horses (Drummond et al., 1959), 25 mg DDVP/kg is cholinergic for sheep, and 10 mg of oral DDVP/kg was toxic for calves (Radeliff and Woodward, 1957) (all studies in Tracy et al., 1960).

Monkeys treated with daily oral doses of DDVP at 20, 40, 80 mg/kg of body weight experienced none of the toxic symptoms typical of organophosphate poisoning or clinical intoxication, e.g., muscle tremors, emesis, dyspnea, ataxia, severe salivation, or convulsions (Hass et al., 1972). However the primary action of DDVP, inhibition of blood cholinesterase activity, was found at levels of oral application from 10, 20, 40 and 80 mg/kg/day. Large oral dosages are necessary to precipitate the appearance of

clinical symptoms because of capacity of the mammalian body to rapidly detoxify DDVP. Dichlorvos therefore has a relatively low chronic mammalian toxicity. Van Raalte (1970) described the effect of DDVP in long-term feeding studies such that, "the dietary level that had no effect on the plasma cholinesterase was .08 mg/kg body weight, whereas a level of 4 mg/kg had no clinical effect." He also related that dogs given DDVP in a slow release formulation tolerated DDVP "with only a minimal clinical effect at a level of 18 mg/kg/day".

Teratogenic Effects. Kimbrough and Gaines (1968) reported some fetal malformations from intraperitoneal (ip) treatment of maternal rats on the 11th day of pregnancy with DDVP (15 mg/kg). They concluded DDVP is slightly teratogenic in Sherman strain rats when a single dose is given ip on the 11th day of gestation. Results from studies done by Thorpe et al. (1972) gave no indication that dichlorvos vapor is teratogenic in rabbits or rats even at exposure concentrations resulting in maternal deaths in rabbits. These results compare with teratogenic studies carried out in rabbits by Vogin et al. (1971) where "no significant difference at nontoxic DDVP doses were found on nidation, in utero survival, or neonatal survival." Effects on fetal development occurred with doses that were markedly toxic.

In three-generation feeding studies on DDVP in pigs (Collins, 1971), no effects on reproductive parameters were detected with dietary levels up to 500 ppm. Witherup et al. (1971) conducted a 2 year feeding study for rats containing up to 500 ppm of DDVP which produced no adverse histological effects on various tissues.

Title 21 - Food and Drugs CFR 558.205 allows the use of 1,000 DDVP mg per head added to the daily feed during the last 30 days of gestation for pregnant swine. Dichlorvos aids in "improving litter production efficiency by increasing pigs born

alive, birth weights, survival to market, and rate of weight gain" (21 CFR 558.205). Swine, however, seem to be much less susceptible to DDVP than most terrestrial organisms.

Metabolism. Hodgson and Casida (1962) found that DDVP in mammalian tissue homogenates and plasma is metabolized enzymatically mainly through hydrolysis of the DDVP to:

- dimethyl phosphate,
- methyl 2,2-dichlorovinyl phosphate (DMD) (with this being further hydrolyzed to monomethyl phosphate and inorganic phosphate),
- dichloroacetaldehyde (DCA),
- dichloroethanol (DCE), and
- dichloroacetic acid (DCAA).

Figure A-3 (from Bibra, 1974) is a diagrammatic representation of the routes of DDVP metabolism, demethylation and hydrolysis.

Oral administration of [^{14}C -Vinyl] DDVP studies performed by Hutson and Hoadley (1972) on the rates and routes of DDVP metabolism for rats, hamsters, a mouse, and a man indicate that metabolism is rapid in all four species and proceeds along similar routes. Hutson and Hoadley found that DCA, the first degradation product, is metabolized by:

- reduction to DCE and excreted in the urine as glucuronide, and
- dechlorination followed by incorporation of the carbon atoms through endogenous biosynthesis and excretion as [^{14}C] carbon dioxide and [^{14}C] hippuric acid in urine.

Dealkylation to DMD is a minor route of biotransformation for rats, hamsters, and man, but constitutes 18.5% of the metabolism for mice (Hutson and Hoadley, 1972). Page et al. (1972) described detoxification in pigs as rapid and proceeding almost entirely by hydrolysis of the phosphate-vinyl bond and then de-

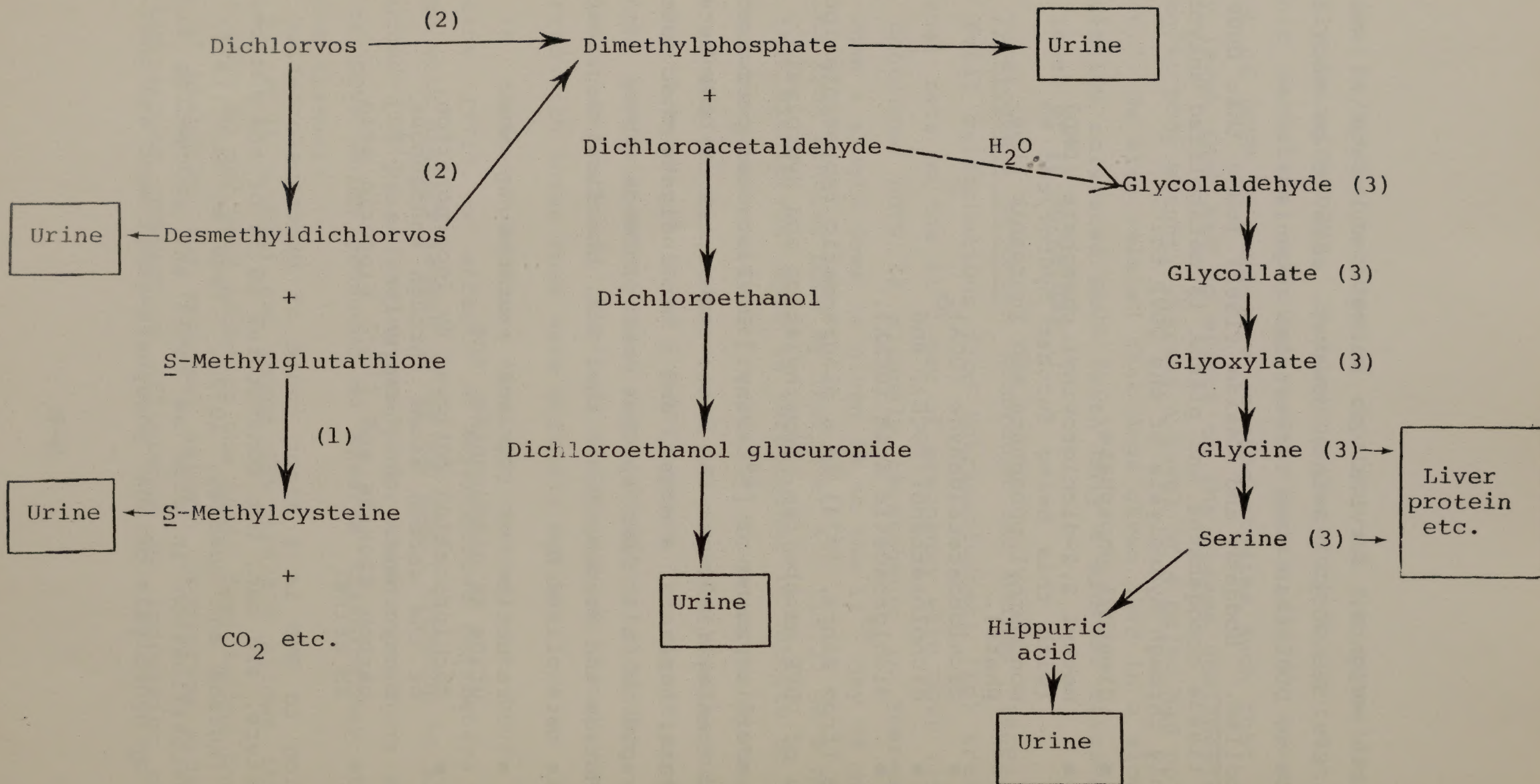


FIGURE A-3

DICHLORVOS METABOLISM; (1) GLUTATHIONE-DEPENDENT DEMETHYLATION AND OXIDATIVE O-DEMETHYLATION; (2) HYDROLYSIS BY LIVER AND BLOOD ENZYMES; (3) ¹⁴C INCORPORATED INTO NORMAL BODY PROCESS (BIBRA, 1974)

chlorination. Because of the difference in metabolism for various species, toxicity, especially chronic toxicity values, may not be extrapolatable.

The half-life of DDVP for in vitro degradation was found to be 20 to 25 minutes at 37 C for both human and pig blood (Page et al., 1972). Blair et al. (1975) also found that DDVP is rapidly degraded in vitro in the blood of rats, rabbits, and humans. Half-lives ranged from 1.5 - 2.2 minutes in rabbits to 13 - 31 minutes in rats and 7 - 12 minutes in humans. Metabolism of an oral dose in mice and rats is almost complete in 24 hours (Bibra, 1974).

A.2 Hazard of Swormlure to Terrestrial Organisms

No information was found concerning the toxicities of swormlure chemicals to terrestrial wildlife and most domestic animals. Toxicity data are available for rats and some other mammals. This information is displayed in Table A-2. Unless otherwise indicated, these are oral toxicity data. The LD₅₀, or median lethal dosage, is a statistical estimate of the dosage that would be lethal to 50% of a population of the test species. The LDL₀ is the lowest published lethal dose.

Except in the case of congeners, no evidence was found to indicate that the swormlure chemicals have synergistic effects or that effects are additive. Congeners are chemicals which are related toxicologically. Among the swormlure chemicals, phenol and p-cresol are congeners, as are acetic, butyric, and valeric acids and iso- and sec-butanol.

Evidence for bioaccumulation of swormlure compounds in animals has not been found. Mehta et al. (1978) found that 60-80% of doses of phenol up to 25 mg/kg was excreted within 24 hours. Phenol is both metabolized and excreted unchanged by rabbits (in Gosselin et al., 1976). A pig excreted most of a percutaneous dose of phenol (90 mg/kg) within eight hours (Pullin et al.,

TABLE A-2
MAMMALIAN TOXICITY DATA FOR SWORMLURE CHEMICALS (mg/kg)

	rat LD ₅₀	mouse LD ₅₀	rabbit LDL ₀	dog	cat	human
Acetic acid	3310	4960	1200	--	--	--
Butyric acid	2940	500 ¹	--	--	--	--
Valeric acid	--	3590 ³	--	--	--	--
Isobutanol	2460	--	3750	--	--	500
Sec-Butanol	6480	--	6000	--	--	--
Phenol	414	300	420	500 ¹	80 ¹	140
p-Cresol	207	344	620	--	80 ¹	--
Benzoic acid	2350	2370	2000 ²	2000 ²	2000 ²	500
Indole	1000	--	--	--	--	--
Dimethyl disulfide	813	--	--	--	--	--

Notes:

- 1 LDL₀
- 2 LD₅₀
- 3 subcutaneous

1978). Since p-cresol is similar to phenol toxicologically and chemically, it would be expected to behave in the same manner. The other swormlure chemicals are products of natural decomposition and fermentation processes, and there is no reason to believe that they would accumulate in animals.

Very little information was found concerning sublethal effects of these chemicals. Veldre and Janes (1979) reported that daily oral administration of volatile phenols (a group which includes phenol and p-cresol) to rats and rabbits at 0.1 LD₅₀ for 7 months resulted in increased blood pressure, loss of weight, and some histological changes in the liver, kidney, and spleen. Daily administration of 0.01 and 0.001 LD₅₀ did not cause such changes.

A.3 Hazard of DDVP to Humans

Acute toxicity data of DDVP for mammalian species are given in Table A-1. The lowest published lethal dose (LDL₀) of DDVP for humans is 50 mg/kg (NIOSH, 1977). ?

Sublethal effects of DDVP on humans should be comparable to the effects on monkeys. Monkeys treated with daily oral doses of DDVP at 20, 40, 80 mg/kg of body weight experienced none of the toxic symptoms typical of organophosphate poisoning or clinical intoxication, e.g., muscle tremors, emesis, dyspnea, ataxia, severe salivation, or convulsions (Hass et al., 1972). However the primary action of DDVP, inhibition of blood cholinesterase activity, was found at levels of oral application from 10, 20, 40 and 80 mg/kg/day. Large oral dosages are necessary to precipitate the appearance of clinical symptoms because of capacity of the mammalian body to rapidly detoxify DDVP and the rapid action characteristics of DDVP. Dichlorvos therefore has a relatively low mammalian toxicity.

DDVP is under pre-RPAR (Rebuttable Presumption Against Registration) review by the U. S. Environmental Protection Agency

for possible mutagenicity, reproductive effects, fetotoxicity and oncogenicity. The following is a review of the literature concerning potential sublethal effects of DDVP exposure.

Mutagenicity. A number of investigations on DDVP's potential mutagenic activity revealed that DDVP is clearly mutagenic in a variety of microorganisms. In contrast, negative results have been consistently obtained in many mammalian mutagenicity tests, including a test for point mutations in vitro, a test for chromosome aberrations in vitro and in vivo, dominant lethal assays, and host-mediated assays with microorganisms as indicator cells (Wild, 1975). Dichlorvos has been shown to alkylate DNA in vitro, but DNA alkylation in vivo has not been shown unequivocally (Kramers and Knapp, 1978). The difference in the in vivo versus in vitro test results is because in the in vitro test the dichlorvos is exposed to bacterial DNA without confrontation from a variety of hydrolytic enzymes, as is the case in for in vivo situations (Hutson and Hoadley, 1972) which explains DDVP's ability to induce mutations in Serratia marcescens under specific in vitro conditions (Dean, 1972b).

Recent investigations have demonstrated the absence of dominant lethal mutations in male mice following single and repeated inhalation exposures to DDVP (Dean and Thorpe, 1972b), the failure of high doses of DDVP to induce chromosome damage in mice and Chinese hamsters (Dean and Thorpe, 1972a), and the absence of cytogenetic changes in human leucocytes cultured in cytotoxic and sub-cytotoxic concentrations of DDVP (Dean, 1972a). From these study results Dean (1972b) concluded that dichlorvos is not a genetic hazard to man or animals. However, in experiments carried out by Dean et al. (1972) it was shown that high concentrations of DDVP in the culture medium can increase the mitotic gene conversion rate in Saccharomyces cerevisiae in vitro, but host-mediated assays using male mice dosed orally with DDVP and Saccharomyces cerevisiae yielded negative results. Rapid metabo-

lism of the compound when given by oral or inhalation routes was cited as the reason for the negative results. Another explanation for positive in vitro results and negative in vivo results is that doses had to be kept relatively lower in the in vivo test (Wild, 1975).

Hanna and Dyer (1975) reported a weak mutagenic effect from DDVP in Drosophila, measured as lethals accumulated during 30 generations of continuous exposure of larvae. Gupta (1974) also reported the ability of DDVP to produce mutations in Drosophila and warned that the ability of a chemical to produce such mutations may not always mean a similar effect in humans, but the potential hazard can not be ruled out. Fischer et al. (1977) studied dichloroacetaldehyde, one of the main degradation products of DDVP, for its possible mutagenic effects in mice in the dominant lethal test. They concluded that it had a demonstrated mutagenic activity.

In a recent review paper on the biochemistry of DDVP, Wright et al. (1979) concluded that although DDVP can induce mutation in bacteria and yeasts, there is no evidence that it produces genotoxic effects in mammals, and that DDVP had been extensively evaluated for mutagenicity and carcinogenicity in mammalian test systems with entirely negative results. It was also concluded that no metabolite of DDVP, including dichloroacetaldehyde, is mutagenic when generated in vivo.

Carcinogenicity. Lofroth (1978) cited two major assays which tested DDVP for carcinogenicity; both resulted in findings of non-carcinogenicity. The first was a 2-year inhalation study in rats where no dose-related increase in tumor risk was found (Blair et al., 1976). The other bioassay was done at the National Cancer Institute. It concluded that DDVP was not demonstrated to be carcinogenic but did not rule out the possibility of tumorigenicity (National Cancer Institute, 1977 in NIOSH, 1978).

Another inhalation study done by Shell at their Tunstall Laboratory using 400 rats produced no evidence of dose-related tumors (Tinker, 1975).

Teratogenicity. Kimbrough and Gaines (1968) reported some fetal malformations from intraperitoneal (ip) treatment of maternal rats on the 11th day of pregnancy with DDVP (15 mg/kg). The conclusion of their study found that DDVP is slightly teratogenic in Sherman strain rats when a single dose is given ip on the 11th day of gestation. Results from studies done by Thorpe et al. (1972) gave no indication that dichlorvos vapor is teratogenic in rabbits or rats even at exposure concentrations resulting in maternal deaths in rabbits. These results compare with teratogenic studies carried out in rabbits by Vogin et al. (1971) where no significant difference at nontoxic DDVP doses were found on nidation, in utero survival, or neonatal survival. Effects on fetal development occurred with doses that were markedly toxic.

In three-generation feeding studies on DDVP in pigs (Collins et al., 1971) no effects on reproductive parameters were detected with dietary levels up to 500 ppm. Witherup et al. (1971) conducted a 2 year feeding study for rats containing up to 500 ppm of DDVP which produced no adverse histological effects for various reproductive tissues.

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Neurotoxicity. Dichlorvos is neurotoxic because of its ability to inhibit cholinesterase activity. It is considered a non-neurotoxic compound by Aldridge and Barnes (1965a), but it can be changed by a "very small" modification into a highly

neurotoxic compound (2-chloro-ethyl 2:2-dichlorovinyl methyl phosphate). Aldridge and Barnes (1965b) tested DDVP in adult hens in order to test its ability to produce a delayed neurotoxic effect (lesions). The results were negative. Few studies have been conclusive on neurotoxicity for mammals.

A.4 Hazards of Swormlure to Humans

The acute toxicities of the chemicals in swormlure are given in Table A-2. It is not known whether or not these chemicals have synergistic effects, nor are the human LD₅₀'s known. It is likely that human LD₅₀'s are comparable to those of rats. Certain individuals may be particularly susceptible to one or more of these chemicals. Lowest published lethal doses (LDL₀'s) for humans of isobutanol, phenol and benzoic acid are also given in Table A-2.

Swormlure chemicals are not known to accumulate in the body, and sublethal effects are not important for all but a few of these substances. However, phenol and p-cresol, indole and isobutanol are listed in the NIOSH Registry (NIOSH, 1978) as possibly causing carcinomas or neoplasms. The hazards of these four chemicals are discussed in detail below.

Phenol. Phenol is toxic to all animals, and symptoms for proportionate quantities are the same among the various species (Gosselin et al., 1976). A reliable LD₅₀ for humans has not been determined. One gram ingested orally is considered dangerous, yet a single dose of over 100 grams has been survived (Arena, 1979). Occasional fatal poisonings have occurred after such slight exposure that hypersensitivity is indicated in some cases (Gosselin et al., 1976). However the lowest fatal dose ingested orally was 140 mg/kg (NIOSH, 1978).

Acute systemic effects caused by oral ingestion of phenol are nausea, vomiting and diarrhea. Cardiovascular irregularity is followed by central nervous system stimulation, respiratory depression, and renal damage (Arena, 1979).

Phenol is a caustic substance. As with most caustic solutions, the response of an individual will depend primarily on the concentration of the phenol rather than volume (Gosselin et al., 1976). A 1% solution has been known to cause skin necrosis (Deichmann & Keplinger, 1962 in Gosselin, 1976) and 10% solutions regularly produce corrosion. In large doses there is a lytic effect on nerves attributed to a temporary anesthetic-like effect and tissue destruction.

Chronic effects of phenol have been studied for applications in industrial health. A seven month test on white rats and rabbits determined that only the largest dose administered (.1 LD₅₀ or 38.6 mg/kg) caused some functional changes. These can be an increase in blood pressure, weight loss, or histological changes of the liver, kidneys and spleen. The use of 0.01 and 0.001 times the LD₅₀ did not cause these changes (Veldre and Janes, 1979).

Phenol at concentrations of .08 to .20% was demonstrated to be mutagenic to E. coli bacteria (Demerec et al., 1951). The greater the concentration of phenol, the more mutations occurred. *Drosophila* gonads exposed in vitro and then implanted into host larvae also indicated mutagenicity because of increased numbers of lethal and semi-lethal mutations (Hadorn and Niggli, 1946 in Dean, 1978). No in vivo mutagenicity has been reported for phenol.

Bulsiewicz (1977) found that phenol in low concentrations (2 ml per day of 0.08 mg/liter solution) produces only minor changes in chromosomes which are probably eliminated by regulative processes in the body, whereas higher doses of phenol (8 mg/liter solution) produce important qualitative and quantitative changes in reproductive cells in mice.

Some evidence that phenol is a carcinogen came from research on its tumor promoting effects in mice. Boutwell and Bosch

(1959) tested combinations of phenol and p-cresol with various promotor and initiator substances. They determined that 10% and 20% concentrations of the compounds alone as well as 5%, 10% and 20% concentrations with other chemical initiators and promoters were capable of causing skin tumors. The response of the animal was found to depend on the quantity of phenol applied as well as the susceptibility of the mouse strain used.

The skin carcinogenicity of phenol appears to be associated with its irritancy and the subsequent skin hyperplasia (Dean, 1978). Dean (1978) found no reference to systemic carcinogenicity for phenol.

In a recent National Cancer Institute carcinogenesis bioassay, phenol was found to be not carcinogenic to male and female F344 rats or male and female B6C3F1 mice.

p-Cresol. p-Cresol, also known as 4-hydroxytoluene or 4-methylphenol, is practically identical to phenol toxicologically. Its acute toxicity is slightly higher (Table A-2). Because phenol and p-cresol are so similar, an extended discussion of p-cresol toxicity is not warranted. Levin and Tjio (1948) in Dean (1978) found that cresols induced c-mitosis (an indicator of mutagenicity) in plant root cells but only marginal evidence of chromosome fragmentation. Sharma and Ghosh (1965) in Dean (1978) attributed the chromosome fragmentation to the meta isomer (m-cresol), but found that application of .025% p-cresol induced c-mitosis and polyploidy. The discussion above concerning the carcinogenicity of phenol is applicable to p-cresol as well. The compound has been scheduled for NTP mutagenicity bioassays in FY 1980.

Indole. Indole is a moderately toxic compound, the oral LD₅₀ in rats being about 1000 mg/kg. A review of the toxicity literature concerning indole reveals a wide range of effects, some of which appear to be carcinogenic.

Roe and Salaman (1955) applied 12 mg of 2% indole biweekly to the skin of 120 mice for nine weeks. It was concluded from the low incidence of tumors (2/120) that indole is not a carcinogenic initiator. The same study correlated indole with an inhibitory effect on aerobic glycolysis by brain tissue in vitro. When the indole was removed, brain tissue activity was not restored.

Ehrhart and Stich (1957) examined indole's role in combination with the spread of leukemia. Twenty mg of indole were injected into two groups of mice, one of which had previously been irradiated. Six months later, myelogenous leukemia cells were injected and their spread subsequently analyzed. The researchers concluded indole should be studied as a carcinogenic promoter, although the specific action of indole in the mice was unclear. They further noted that a possible effect of chronic indole intoxication may be degenerative changes in several organ tissues.

Matsumoto et al. (1976) studied the effect of indole on carcinogenesis in hamsters. In conjunction with a-acetyl amino-fluorene (AAF), a known carcinogen, indole is implicated as a tumor promoter. After ten months, AAF given as .03% of total diet produced a 50% incidence of bladder tumors, while .03% AAF with 1.6% indole produced a 90% incidence. Conversely, indole was observed to suppress AAF hepatocarcinogenicity in the same group of hamsters. One possible explanation is that indole changes the metabolism of AAF in the liver and this metabolite may be diverted to the bladder before it can affect the liver. Another finding was that male hamsters were found to be more susceptible to tumors than female hamsters.

In another study by Matsumoto et al. (1977) indole was shown to suppress bladder carcinomas caused by dibutyl nitrosamine (DBN). Over an eight month period hamsters were given a total of $20.3 \pm .7$ g indole in their diet along with $0.1041 \pm .024$ g DBN.

This study demonstrated that the incidence of bladder tumors was higher in groups given only DBN than in those given DBN and indole. It is not known whether the bladder tumor suppression by dietary indole is temporary or permanent.

Isobutanol. Isobutanol is moderately toxic (Table A-2) and may be mildly irritating to skin and mucous membranes. Only one study was found concerning chronic effects of isobutanol exposure. Rats were fed 200 mg/kg isobutanol twice weekly until 29,000 mg was ingested (Gibel et al., 1975). Three malignant and 9 benign tumors were found in 19 rats. Liver necrosis and haematotoxic effects were also observed.

APPENDIX B
TABLES AND FIGURES FOR ECONOMIC ANALYSES

TABLE B.1

NATIVE FEMALES/SQ. MI. IN (I+1)ST GENERATION																
STERILE MALES																
GROWTH RATE = 1																
COMPETITIVE STERILE MALES	NATIVE FEMALES/SQ. MI. IN ITH GENERATION															
	250	200	160	120	100	80	70	60	50	40	30	20	15	10		
2000 *	28	18	12	7	5	3	2	2	1	1	0	0	0	0	0	0
1900 *	29	19	12	7	5	3	2	2	1	1	0	0	0	0	0	0
1800 *	30	20	13	8	5	3	3	2	1	1	0	0	0	0	0	0
1700 *	32	21	14	8	6	4	3	2	1	1	1	0	0	0	0	0
1600 *	34	22	15	8	6	4	3	2	2	1	1	0	0	0	0	0
1500 *	36	24	15	9	6	4	3	2	2	1	1	0	0	0	0	0
1400 *	38	25	16	9	7	4	3	2	2	1	1	0	0	0	0	0
1300 *	40	27	18	10	7	5	4	3	2	1	1	0	0	0	0	0
1200 *	43	29	19	11	8	5	4	3	2	1	1	0	0	0	0	0
1100 *	46	31	20	12	8	5	4	3	2	1	1	0	0	0	0	0
1000 *	50	33	22	13	9	6	5	3	2	2	1	0	0	0	0	0
950 *	52	35	23	13	10	6	5	4	3	2	1	0	0	0	0	0
900 *	54	36	24	14	10	7	5	4	3	2	1	0	0	0	0	0
850 *	57	38	25	15	11	7	5	4	3	2	1	0	0	0	0	0
800 *	60	40	27	16	11	7	6	4	3	2	1	0	0	0	0	0
750 *	63	42	28	17	12	8	6	4	3	2	1	1	0	0	0	0
700 *	66	44	30	18	13	8	6	5	3	2	1	1	0	0	0	0
650 *	69	47	32	19	13	9	7	5	4	2	1	1	0	0	0	0
600 *	74	50	34	20	14	9	7	5	4	3	1	1	0	0	0	0
550 *	78	53	36	21	15	10	8	6	4	3	2	1	0	0	0	0
500 *	83	57	39	23	17	11	9	6	5	3	2	1	0	0	0	0
450 *	89	62	42	25	18	12	9	7	5	3	2	1	0	0	0	0
400 *	96	67	46	28	20	13	10	8	6	4	2	1	1	0	0	0
350 *	104	73	50	31	22	15	12	9	6	4	2	1	1	0	0	0
300 *	114	80	56	34	25	17	13	10	7	5	3	1	1	0	0	0
250 *	125	89	62	39	29	19	15	12	8	6	3	1	1	0	0	0
200 *	139	100	71	45	33	23	18	14	10	7	4	2	1	0	0	0
175 *	147	107	76	49	36	25	20	15	11	7	4	2	1	1	0	0
150 *	156	114	83	53	40	28	22	17	13	8	5	2	1	1	0	0
125 *	167	123	90	59	44	31	25	19	14	10	6	3	2	1	0	0
100 *	179	133	98	65	50	36	29	23	17	11	7	3	2	1	0	0
75 *	192	145	109	74	57	41	34	27	20	14	9	4	3	1	0	0
50 *	208	160	122	85	67	49	41	33	25	18	11	6	3	2	0	0
25 *	227	178	138	99	80	61	52	42	33	25	16	9	6	3	1	0
0 *	250	200	160	120	100	80	70	60	50	40	30	20	15	10	5	0

B-1

TABLE B.1 (Continued)

NATIVE FEMALES/SQ. MI. IN (I+1)ST GENERATION
 STERILE MALES/SWASS
 GROWTH RATE = 1

COMPETITIVE
 STERILE
 MALES

NATIVE FEMALES/SQ. MI. IN ITH GENERATION

	250	200	160	120	100	80	70	60	50	40	30	20	15	10	5
2000 *	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0
1900 *	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0
1800 *	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0
1700 *	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0
1600 *	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0
1500 *	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0
1400 *	2	1	1	1	0	0	0	0	0	0	0	0	0	0	0
1300 *	2	1	1	1	0	0	0	0	0	0	0	0	0	0	0
1200 *	2	2	1	1	0	0	0	0	0	0	0	0	0	0	0
1100 *	3	2	1	1	0	0	0	0	0	0	0	0	0	0	0
1000 *	3	2	1	1	0	0	0	0	0	0	0	0	0	0	0
950 *	3	2	1	1	1	0	0	0	0	0	0	0	0	0	0
900 *	3	2	1	1	1	0	0	0	0	0	0	0	0	0	0
850 *	3	2	1	1	1	0	0	0	0	0	0	0	0	0	0
800 *	4	2	2	1	1	0	0	0	0	0	0	0	0	0	0
750 *	4	3	2	1	1	0	0	0	0	0	0	0	0	0	0
700 *	4	3	2	1	1	0	0	0	0	0	0	0	0	0	0
650 *	4	3	2	1	1	0	0	0	0	0	0	0	0	0	0
600 *	5	3	2	1	1	1	0	0	0	0	0	0	0	0	0
550 *	5	3	2	1	1	1	0	0	0	0	0	0	0	0	0
500 *	6	4	2	1	1	1	0	0	0	0	0	0	0	0	0
450 *	6	4	3	2	1	1	1	0	0	0	0	0	0	0	0
400 *	7	4	3	2	1	1	1	0	0	0	0	0	0	0	0
350 *	8	5	3	2	1	1	1	0	0	0	0	0	0	0	0
300 *	9	6	4	2	2	1	1	1	0	0	0	0	0	0	0
250 *	10	7	4	3	2	1	1	1	0	0	0	0	0	0	0
200 *	12	8	5	3	2	1	1	1	1	0	0	0	0	0	0
175 *	13	9	6	4	3	2	1	1	1	0	0	0	0	0	0
150 *	15	10	7	4	3	2	1	1	1	1	0	0	0	0	0
125 *	17	11	8	5	3	2	2	1	1	1	0	0	0	0	0
100 *	19	13	9	6	4	3	2	2	1	1	0	0	0	0	0
75 *	23	16	11	7	5	3	3	2	1	1	1	0	0	0	0
50 *	28	20	14	9	7	5	4	3	2	1	1	0	0	0	0
25 *	36	27	20	13	10	7	6	5	3	2	1	1	0	0	0
0 *	50	40	32	24	20	16	14	12	10	8	6	4	3	2	1

TABLE B.1 (Continued)

NATIVE FEMALES/SQ. MI. IN (I+1)ST GENERATION
 STERILE MALES
 GROWTH RATE = 3

COMPETITIVE
 STERILE
 MALES

NATIVE FEMALES/SQ. MI. IN ITH GENERATION

250 200 160 120 100 80 70 60 50 40 30 20 15 10

	250	200	160	120	100	80	70	60	50	40	30	20	15	10
2000 *	83	55	36	20	14	9	7	5	4	2	1	1	0	0
1900 *	87	57	37	21	15	10	7	6	4	2	1	1	0	0
1800 *	91	60	39	23	16	10	8	6	4	3	1	1	0	0
1700 *	96	63	41	24	17	11	8	6	4	3	2	1	0	0
1600 *	101	67	44	25	18	11	9	7	5	3	2	1	0	0
1500 *	107	71	46	27	19	12	9	7	5	3	2	1	0	0
1400 *	114	75	49	28	20	13	10	7	5	3	2	1	0	0
1300 *	121	80	53	30	21	14	11	8	6	4	2	1	1	0
1200 *	129	86	56	33	23	15	12	9	6	4	2	1	1	0
1100 *	139	92	61	35	25	16	13	9	7	4	2	1	1	0
1000 *	150	100	66	39	27	18	14	10	7	5	3	1	1	0
950 *	156	104	69	40	29	19	14	11	8	5	3	1	1	0
900 *	163	109	72	42	30	20	15	11	8	5	3	1	1	0
850 *	170	114	76	45	32	21	16	12	8	5	3	1	1	0
800 *	179	120	80	47	33	22	17	13	9	6	3	1	1	0
750 *	188	126	84	50	35	23	18	13	9	6	3	2	1	0
700 *	197	133	89	53	38	25	19	14	10	6	4	2	1	0
650 *	208	141	95	56	40	26	20	15	11	7	4	2	1	0
600 *	221	150	101	60	43	28	22	16	12	8	4	2	1	0
550 *	234	160	108	64	46	30	24	18	13	8	5	2	1	0
500 *	250	171	116	70	50	33	26	19	14	9	5	2	1	0
450 *	268	185	126	76	55	36	28	21	15	10	6	3	1	0
400 *	288	200	137	83	60	40	31	23	17	11	6	3	2	1
350 *	313	218	151	92	67	45	35	26	19	12	7	3	2	1
300 *	341	240	167	103	75	51	40	30	21	14	8	4	2	1
250 *	375	267	187	117	86	58	46	35	25	17	10	4	3	1
200 *	417	300	213	135	100	69	54	42	30	20	12	5	3	1
175 *	441	320	229	146	109	75	60	46	33	22	13	6	4	2
150 *	469	343	248	160	120	83	67	51	38	25	15	7	4	2
125 *	500	369	269	176	133	94	75	58	43	29	17	8	5	2
100 *	536	400	295	196	150	107	86	68	50	34	21	10	6	3
75 *	577	436	327	222	171	124	101	80	60	42	26	13	8	4
50 *	625	480	366	254	200	148	123	98	75	53	34	17	10	5
25 *	682	533	415	298	240	183	155	127	100	74	49	27	17	9
0 *	750	600	480	360	300	240	210	180	150	120	90	60	45	30

B-3

TABLE B.1 (Continued)

NATIVE FEMALES/SQ.MI. IN (I+1)ST GENERATION
 STERILE MALES/SWASS
 GROWTH RATE = 3

COMPETITIVE
 STERILE
 MALES

NATIVE FEMALES/SQ.MI. IN ITH GENERATION

250 200 160 120 100 80 70 60 50 40 30 20 15 10 5

	250	200	160	120	100	80	70	60	50	40	30	20	15	10	5
2000 *	5	3	2	1	1	0	0	0	0	0	0	0	0	0	0
1900 *	5	3	2	1	1	1	0	0	0	0	0	0	0	0	0
1800 *	5	3	2	1	1	1	0	0	0	0	0	0	0	0	0
1700 *	5	3	2	1	1	1	0	0	0	0	0	0	0	0	0
1600 *	6	4	2	1	1	1	0	0	0	0	0	0	0	0	0
1500 *	6	4	2	1	1	1	0	0	0	0	0	0	0	0	0
1400 *	6	4	3	2	1	1	1	0	0	0	0	0	0	0	0
1300 *	7	4	3	2	1	1	1	0	0	0	0	0	0	0	0
1200 *	7	5	3	2	1	1	1	0	0	0	0	0	0	0	0
1100 *	8	5	3	2	1	1	1	0	0	0	0	0	0	0	0
1000 *	9	6	4	2	1	1	1	1	0	0	0	0	0	0	0
950 *	9	6	4	2	2	1	1	1	0	0	0	0	0	0	0
900 *	10	6	4	2	2	1	1	1	0	0	0	0	0	0	0
850 *	10	7	4	2	2	1	1	1	0	0	0	0	0	0	0
800 *	11	7	5	3	2	1	1	1	0	0	0	0	0	0	0
750 *	12	8	5	3	2	1	1	1	1	0	0	0	0	0	0
700 *	12	8	5	3	2	1	1	1	1	0	0	0	0	0	0
650 *	13	9	6	3	2	1	1	1	1	0	0	0	0	0	0
600 *	14	9	6	3	2	2	1	1	1	0	0	0	0	0	0
550 *	15	10	7	4	3	2	1	1	1	0	0	0	0	0	0
500 *	17	11	7	4	3	2	1	1	1	0	0	0	0	0	0
450 *	18	12	8	5	3	2	2	1	1	1	0	0	0	0	0
400 *	20	13	9	5	4	2	2	1	1	1	0	0	0	0	0
350 *	23	15	10	6	4	3	2	1	1	1	0	0	0	0	0
300 *	26	17	11	7	5	3	2	2	1	1	0	0	0	0	0
250 *	30	20	13	8	5	4	3	2	1	1	1	0	0	0	0
200 *	36	24	16	9	7	4	3	3	2	1	1	0	0	0	0
175 *	39	27	18	11	8	5	4	3	2	2	1	0	0	0	0
150 *	44	30	20	12	9	6	4	3	2	2	1	0	0	0	0
125 *	50	34	23	14	10	7	5	4	3	2	1	0	0	0	0
100 *	58	40	27	17	12	8	6	5	3	2	1	1	0	0	0
75 *	68	48	33	21	15	10	8	6	4	3	2	1	0	0	0
50 *	83	60	43	27	20	14	11	8	6	4	2	1	1	0	0
25 *	107	80	59	39	30	21	17	14	10	7	4	2	1	1	0
0 *	150	120	96	72	60	48	42	36	30	24	18	12	9	6	3

TABLE B.1 (Continued)

		NATIVE FEMALES/SQ. MI. IN (I+1)ST GENERATION															
		STERILE MALES															
		GROWTH RATE = 5															
B-5	COMPETITIVE STERILE MALES	NATIVE FEMALES/SQ. MI. IN ITH GENERATION															
		250	200	160	120	100	80	70	60	50	40	30	20	15	10		
	2000 *	139	91	59	34	24	15	12	9	6	4	2	1	1	0	0	
	1900 *	145	95	62	36	25	16	12	9	6	4	2	1	1	0	0	
	1800 *	152	100	65	38	26	17	13	10	7	4	2	1	1	0	0	
	1700 *	160	105	69	40	28	18	14	10	7	5	3	1	1	0	0	
	1600 *	169	111	73	42	29	19	15	11	8	5	3	1	1	0	0	
	1500 *	179	118	77	44	31	20	16	12	8	5	3	1	1	0	0	
	1400 *	189	125	82	47	33	22	17	12	9	6	3	1	1	0	0	
	1300 *	202	133	88	51	36	23	18	13	9	6	3	2	1	0	0	
	1200 *	216	143	94	55	38	25	19	14	10	6	4	2	1	0	0	
	1100 *	231	154	102	59	42	27	21	16	11	7	4	2	1	0	0	
	1000 *	250	167	110	64	45	30	23	17	12	8	4	2	1	0	0	
	950 *	260	174	115	67	48	31	24	18	13	8	5	2	1	1	0	
	900 *	272	182	121	71	50	33	25	19	13	9	5	2	1	1	0	
	850 *	284	190	127	74	53	34	27	20	14	9	5	2	1	1	0	
	800 *	298	200	133	78	56	36	28	21	15	10	5	2	1	1	0	
	750 *	313	211	141	83	59	39	30	22	16	10	5	2	1	1	0	
	700 *	329	222	149	88	63	41	32	24	17	11	6	3	1	1	0	
	650 *	347	235	158	94	67	44	34	25	18	12	7	3	2	1	0	
	600 *	368	250	168	100	71	47	37	27	19	13	7	3	2	1	0	
	550 *	391	267	180	107	77	51	40	30	21	14	8	4	2	1	0	
	500 *	417	286	194	116	83	55	43	32	23	15	8	4	2	1	0	
	450 *	446	308	210	126	91	60	47	35	25	16	9	4	2	1	0	
	400 *	481	333	229	138	100	67	52	39	28	18	10	4	2	1	0	
	350 *	521	364	251	153	111	74	58	44	31	21	12	5	3	1	0	
	300 *	568	400	278	171	125	84	66	50	36	24	14	6	4	2	0	
	250 *	625	444	312	195	143	97	77	58	42	28	16	7	4	2	0	
	200 *	694	500	356	225	167	114	91	69	50	33	20	9	5	2	1	
	175 *	735	533	382	244	182	125	100	77	56	37	22	10	6	3	1	
	150 *	781	571	413	267	200	139	111	86	63	42	25	12	7	3	1	
	125 *	833	615	443	294	222	156	126	97	71	48	29	14	8	4	1	
	100 *	893	667	492	327	250	178	144	113	83	57	35	17	10	5	1	
	75 *	962	727	545	369	286	206	169	133	100	70	43	21	13	6	2	
	50 *	1042	800	610	424	333	246	204	164	125	89	56	29	17	8	2	
	25 *	1136	889	692	497	400	305	258	212	167	123	82	44	28	14	4	
	0 *	1250	1000	800	600	500	400	350	300	250	200	150	100	75	50	25	

TABLE B.1 (Continued)

NATIVE FEMALES/SQ. MI. IN (I+1)ST GENERATION
 STERILE MALES/SWASS
 GROWTH RATE = 5

COMPETITIVE
 STERILE
 MALES

NATIVE FEMALES/SQ. MI. IN ITH GENERATION

	250	200	160	120	100	80	70	60	50	40	30	20	15	10	5
2000 *	8	5	3	2	1	1	1	0	0	0	0	0	0	0	0
1900 *	8	5	3	2	1	1	1	0	0	0	0	0	0	0	0
1800 *	8	5	3	2	1	1	1	0	0	0	0	0	0	0	0
1700 *	9	6	4	2	1	1	1	1	0	0	0	0	0	0	0
1600 *	9	6	4	2	2	1	1	1	0	0	0	0	0	0	0
1500 *	10	6	4	2	2	1	1	1	0	0	0	0	0	0	0
1400 *	11	7	4	3	2	1	1	1	0	0	0	0	0	0	0
1300 *	11	7	5	3	2	1	1	1	0	0	0	0	0	0	0
1200 *	12	8	5	3	2	1	1	1	1	0	0	0	0	0	0
1100 *	13	9	6	3	2	1	1	1	1	0	0	0	0	0	0
1000 *	15	10	6	3	2	2	1	1	1	0	0	0	0	0	0
950 *	15	10	6	4	3	2	1	1	1	0	0	0	0	0	0
900 *	16	11	7	4	3	2	1	1	1	0	0	0	0	0	0
850 *	17	11	7	4	3	2	1	1	1	0	0	0	0	0	0
800 *	18	12	8	4	3	2	1	1	1	0	0	0	0	0	0
750 *	19	13	8	5	3	2	2	1	1	1	0	0	0	0	0
700 *	20	13	9	5	3	2	2	1	1	1	0	0	0	0	0
650 *	22	14	9	5	4	2	2	1	1	1	0	0	0	0	0
600 *	24	15	10	6	4	3	2	1	1	1	0	0	0	0	0
550 *	26	17	11	6	4	3	2	2	1	1	0	0	0	0	0
500 *	28	18	12	7	5	3	2	2	1	1	0	0	0	0	0
450 *	30	20	13	8	5	3	3	2	1	1	0	0	0	0	0
400 *	34	22	15	8	6	4	3	2	2	1	1	0	0	0	0
350 *	38	25	16	9	7	4	3	2	2	1	1	0	0	0	0
300 *	43	29	19	11	8	5	4	3	2	2	1	0	0	0	0
250 *	50	33	22	13	9	6	5	4	3	2	1	0	0	0	0
200 *	60	40	27	16	11	7	6	5	4	3	2	1	0	0	0
175 *	66	44	30	18	13	8	6	5	4	3	2	1	0	0	0
150 *	74	50	34	20	14	9	7	5	4	3	2	1	0	0	0
125 *	83	57	39	23	17	11	9	6	5	4	2	1	1	0	0
100 *	96	67	46	28	20	13	10	8	6	4	3	1	1	0	0
75 *	114	80	56	34	25	17	13	10	7	5	3	2	1	0	0
50 *	139	100	71	45	33	23	18	14	10	7	4	2	1	0	0
25 *	179	133	98	65	50	36	29	23	17	11	7	3	2	1	0
0 *	250	200	160	120	100	80	70	60	50	40	30	20	15	10	5

TABLE B.1 (Continued)

NATIVE FEMALES/SQ. MI. IN (I+1)ST GENERATION															
STERILE MALES															
GROWTH RATE = 10															
COMPETITIVE STERILE MALES	NATIVE FEMALES/SQ. MI. IN ITH GENERATION														
	250	200	160	120	100	80	70	60	50	40	30	20	15	10	
2000 *	278	182	119	68	48	31	24	17	12	8	4	2	1	0	0
1900 *	291	190	124	71	50	32	25	18	13	8	5	2	1	1	0
1800 *	305	200	131	75	53	34	26	19	14	9	5	2	1	1	0
1700 *	321	211	138	79	56	36	28	20	14	9	5	2	1	1	0
1600 *	338	222	145	84	59	38	29	22	15	10	6	2	1	1	0
1500 *	357	235	154	89	63	41	31	23	16	10	6	3	1	1	0
1400 *	379	250	164	95	67	43	33	25	17	11	6	3	2	1	0
1300 *	403	267	175	101	71	46	36	26	19	12	7	3	2	1	0
1200 *	431	286	188	109	77	50	39	29	20	13	7	3	2	1	0
1100 *	463	308	203	118	83	54	42	31	22	14	8	4	2	1	0
1000 *	500	333	221	129	91	59	46	34	24	15	9	4	2	1	0
950 *	521	348	231	135	95	62	48	36	25	16	9	4	2	1	0
900 *	543	364	242	141	100	65	51	38	26	17	10	4	2	1	0
850 *	568	381	253	148	105	69	53	40	28	18	10	5	3	1	0
800 *	595	400	267	157	111	73	56	42	29	19	11	5	3	1	0
750 *	625	421	281	166	118	77	60	44	31	20	12	5	3	1	0
700 *	658	444	298	176	125	82	64	47	33	22	12	5	3	1	0
650 *	694	471	316	187	133	88	68	51	36	23	13	6	3	1	0
600 *	735	500	337	200	143	94	73	55	38	25	14	6	3	2	0
550 *	781	533	361	215	154	102	79	59	42	27	16	7	4	2	0
500 *	833	571	388	232	167	110	86	64	45	30	17	8	4	2	0
450 *	893	615	420	253	182	121	94	71	50	33	19	9	5	2	1
400 *	962	667	457	277	200	133	104	78	56	36	21	10	5	2	1
350 *	1042	727	502	306	222	149	117	88	63	41	24	11	6	3	1
300 *	1136	800	557	343	250	168	132	100	71	47	27	13	7	3	1
250 *	1250	889	624	389	286	194	153	116	83	55	32	15	8	4	1
200 *	1389	1000	711	450	333	229	181	138	100	67	39	18	10	5	1
175 *	1471	1067	764	488	364	251	200	153	111	74	44	21	12	5	1
150 *	1563	1143	826	533	400	278	223	171	125	84	50	24	14	6	2
125 *	1667	1231	898	588	444	312	251	195	143	97	58	28	16	7	2
100 *	1786	1333	985	655	500	356	288	225	167	114	69	33	20	9	2
75 *	1923	1455	1089	738	571	413	338	267	200	139	86	42	25	12	3
50 *	2083	1600	1219	847	667	492	408	327	250	178	113	57	35	17	5
25 *	2273	1778	1384	993	800	610	516	424	333	246	164	89	56	29	8
0 *	2500	2000	1600	1200	1000	800	700	600	500	400	300	200	150	100	50

TABLE B.1 (Continued)

		NATIVE FEMALES/SQ. MI. IN (I+1)ST GENERATION														STERILE MALES/SWASS		GROWTH RATE = 10	
		NATIVE FEMALES/SQ. MI. IN ITH GENERATION																	
COMPETITIVE STERILE MALES		250	200	160	120	100	80	70	60	50	40	30	20	15	10	5			
B-8	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	
	2000 *	15	10	6	4	2	2	1	1	1	0	0	0	0	0	0	0		
	1900 *	16	10	7	4	3	2	1	1	1	0	0	0	0	0	0	0		
	1800 *	17	11	7	4	3	2	1	1	1	0	0	0	0	0	0	0		
	1700 *	18	11	7	4	3	2	1	1	1	0	0	0	0	0	0	0		
	1600 *	19	12	8	4	3	2	2	1	1	0	0	0	0	0	0	0		
	1500 *	20	13	8	5	3	2	2	1	1	1	0	0	0	0	0	0		
	1400 *	21	14	9	5	4	2	2	1	1	1	0	0	0	0	0	0		
	1300 *	23	15	10	5	4	2	2	1	1	1	0	0	0	0	0	0		
	1200 *	25	16	10	6	4	3	2	1	1	1	0	0	0	0	0	0		
	1100 *	27	17	11	6	4	3	2	2	1	1	0	0	0	0	0	0		
	1000 *	29	19	12	7	5	3	2	2	1	1	0	0	0	0	0	0		
	950 *	31	20	13	7	5	3	3	2	1	1	0	0	0	0	0	0		
	900 *	32	21	14	8	5	3	3	2	1	1	0	0	0	0	0	0		
	850 *	34	22	14	8	6	4	3	2	1	1	1	0	0	0	0	0		
	800 *	36	24	15	9	6	4	3	2	2	1	1	0	0	0	0	0		
	750 *	38	25	16	9	6	4	3	2	2	1	1	0	0	0	0	0		
	700 *	41	27	17	10	7	4	3	3	2	1	1	0	0	0	0	0		
	650 *	44	29	19	11	7	5	4	3	2	1	1	0	0	0	0	0		
	600 *	47	31	20	11	8	5	4	3	2	1	1	0	0	0	0	0		
550 *	51	33	22	12	9	6	4	3	2	1	1	0	0	0	0	0			
500 *	56	36	24	14	10	6	5	3	2	2	1	0	0	0	0	0			
450 *	61	40	26	15	11	7	5	4	3	2	1	0	0	0	0	0			
400 *	68	44	29	17	12	8	6	4	3	2	1	0	0	0	0	0			
350 *	76	50	33	19	13	9	7	5	3	2	1	1	0	0	0	0			
300 *	86	57	38	22	15	10	8	6	4	3	1	1	0	0	0	0			
250 *	100	67	44	26	18	12	9	7	5	3	2	1	0	0	0	0			
200 *	119	80	53	31	22	15	11	8	6	4	2	1	1	0	0	0			
175 *	132	89	60	35	25	16	13	9	7	4	2	1	1	0	0	0			
150 *	147	100	67	40	29	19	15	11	8	5	3	1	1	0	0	0			
125 *	167	114	78	46	33	22	17	13	9	6	3	2	1	0	0	0			
100 *	192	133	91	55	40	27	21	16	11	7	4	2	1	0	0	0			
75 *	227	160	111	69	50	34	26	20	14	9	5	3	1	1	0	0			
50 *	278	200	142	90	67	46	36	28	20	13	8	4	2	1	0	0			
25 *	357	267	197	131	100	71	58	45	33	23	14	7	4	2	0	0			
0 *	500	400	320	240	200	160	140	120	100	80	60	40	30	20	10				

TABLE B.1 (Continued)

		NATIVE FEMALES/SQ. MI. IN (I+1)ST GENERATION															
		STERILE MALES															
		GROWTH RATE = 20															
B-9	COMPETITIVE STERILE MALES	NATIVE FEMALES/SQ. MI. IN ITH GENERATION															
		250	200	160	120	100	80	70	60	50	40	30	20	15	10		
		*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****		
	2000 *	556	364	237	136	95	62	47	35	24	16	9	4	2	1	0	
	1900 *	581	381	249	143	100	65	50	37	26	16	9	4	2	1	0	
	1800 *	610	400	261	150	105	68	52	39	27	17	10	4	2	1	0	
	1700 *	641	421	275	158	111	72	55	41	29	18	10	5	3	1	0	
	1600 *	676	444	291	167	118	76	59	43	30	20	11	5	3	1	0	
	1500 *	714	471	308	178	125	81	62	46	32	21	12	5	3	1	0	
	1400 *	758	500	328	189	133	86	67	49	34	22	13	6	3	1	0	
	1300 *	806	533	351	203	143	93	72	53	37	24	14	6	3	2	0	
	1200 *	862	571	376	218	154	100	77	57	40	26	15	7	4	2	0	
	1100 *	926	615	406	236	167	108	84	62	43	28	16	7	4	2	0	
	1000 *	1000	667	441	257	182	119	92	68	48	31	17	8	4	2	0	
	950 *	1042	696	461	269	190	124	96	71	50	32	18	8	5	2	1	
	900 *	1087	727	483	282	200	131	101	75	53	34	19	9	5	2	1	
	850 *	1136	762	507	297	211	138	107	79	56	36	20	9	5	2	1	
	800 *	1190	800	533	313	222	145	113	84	59	38	22	10	6	2	1	
	750 *	1250	842	563	331	235	154	120	89	63	41	23	10	6	3	1	
	700 *	1316	889	595	351	250	164	127	95	67	43	25	11	6	3	1	
	650 *	1389	941	632	374	267	175	136	101	71	46	26	12	7	3	1	
	600 *	1471	1000	674	400	286	188	146	109	77	50	29	13	7	3	1	
	550 *	1563	1067	721	430	308	203	158	118	83	54	31	14	8	4	1	
	500 *	1667	1143	776	465	333	221	172	129	91	59	34	15	9	4	1	
	450 *	1786	1231	839	505	364	242	188	141	100	65	38	17	10	4	1	
	400 *	1923	1333	914	554	400	267	209	157	111	73	42	19	11	5	1	
	350 *	2083	1455	1004	613	444	298	233	176	125	82	47	22	12	6	1	
	300 *	2273	1600	1113	686	500	337	265	200	143	94	55	25	14	6	2	
	250 *	2500	1778	1249	778	571	388	306	232	167	110	64	30	17	8	2	
	200 *	2778	2000	1422	900	667	457	363	277	200	133	78	36	21	10	2	
	175 *	2941	2133	1528	976	727	502	400	306	222	149	88	41	24	11	3	
	150 *	3125	2286	1652	1067	800	557	445	343	250	168	100	47	27	13	3	
	125 *	3333	2462	1796	1176	889	624	503	389	286	194	116	55	32	15	4	
	100 *	3571	2667	1969	1309	1000	711	576	450	333	229	138	67	39	18	5	
	75 *	3846	2909	2179	1477	1143	826	676	533	400	278	171	84	50	24	6	
	50 *	4167	3200	2438	1694	1333	985	817	655	500	356	225	114	69	33	9	
	25 *	4545	3556	2768	1986	1600	1219	1032	847	667	492	327	178	113	57	17	
	0 *	5000	4000	3200	2400	2000	1600	1400	1200	1000	800	600	400	300	200	100	

TABLE B.1 (Continued)

NATIVE FEMALES/SQ. MI. IN (I+1)ST GENERATION																	
STERILE MALES/SWASS																	
GROWTH RATE = 20																	
COMPETITIVE STERILE MALES		NATIVE FEMALES/SQ. MI. IN ITH GENERATION															
		250	200	160	120	100	80	70	60	50	40	30	20	15	10	5	

B-10	2000 *	30	20	13	7	5	3	2	2	1	1	0	0	0	0	0	
	1900 *	32	21	13	7	5	3	3	2	1	1	0	0	0	0	0	
	1800 *	34	22	14	8	5	4	3	2	1	1	0	0	0	0	0	
	1700 *	35	23	15	8	6	4	3	2	1	1	1	0	0	0	0	
	1600 *	38	24	16	9	6	4	3	2	2	1	1	0	0	0	0	
	1500 *	40	26	17	9	7	4	3	2	2	1	1	0	0	0	0	
	1400 *	43	28	18	10	7	5	3	3	2	1	1	0	0	0	0	
	1300 *	46	30	19	11	8	5	4	3	2	1	1	0	0	0	0	
	1200 *	50	32	21	12	8	5	4	3	2	1	1	0	0	0	0	
	1100 *	54	35	22	13	9	6	4	3	2	1	1	0	0	0	0	
	1000 *	59	38	25	14	10	6	5	4	2	2	1	0	0	0	0	
	950 *	62	40	26	15	10	7	5	4	3	2	1	0	0	0	0	
	900 *	65	42	27	15	11	7	5	4	3	2	1	0	0	0	0	
	850 *	68	44	29	16	11	7	6	4	3	2	1	0	0	0	0	
	800 *	72	47	30	17	12	8	6	4	3	2	1	0	0	0	0	
	750 *	77	50	32	18	13	8	6	5	3	2	1	1	0	0	0	
	700 *	82	53	35	20	14	9	7	5	4	2	1	1	0	0	0	
	650 *	88	57	37	21	15	10	7	5	4	2	1	1	0	0	0	
	600 *	94	62	40	23	16	10	8	6	4	3	1	1	0	0	0	
	550 *	102	67	43	25	17	11	9	6	4	3	2	1	0	0	0	
500 *	111	73	47	27	19	12	9	7	5	3	2	1	0	0	0		
450 *	122	80	52	30	21	14	10	8	5	3	2	1	0	0	0		
400 *	135	89	58	33	24	15	12	9	6	4	2	1	1	0	0		
350 *	152	100	66	38	27	17	13	10	7	4	3	1	1	0	0		
300 *	172	114	75	44	31	20	15	11	8	5	3	1	1	0	0		
250 *	200	133	88	51	36	24	18	14	10	6	3	2	1	0	0		
200 *	238	160	107	63	44	29	23	17	12	8	4	2	1	0	0		
175 *	263	178	119	70	50	33	25	19	13	9	5	2	1	1	0		
150 *	294	200	135	80	57	38	29	22	15	10	6	3	1	1	0		
125 *	333	229	155	93	67	44	34	26	18	12	7	3	2	1	0		
100 *	385	267	183	111	80	53	42	31	22	15	8	4	2	1	0		
75 *	455	320	223	137	100	67	53	40	29	19	11	5	3	1	0		
50 *	556	400	284	180	133	91	73	55	40	27	16	7	4	2	0		
25 *	714	533	394	262	200	142	115	90	67	46	28	13	8	4	1		
0 *	1000	800	640	480	400	320	280	240	200	160	120	80	60	40	20		

TABLE B.2

		COSTS FOR EQUAL EFFECTIVENESS WITH STERILE MALES NATIVE FEMALES/SQ. MI.													
COMPETITIVE NESS	STERILE FLIES RELEASED	SWASS PROGRAM COST	*	200	160	120	100	80	60	40	30	20	15	10	5

B-11 .125	2000	33.72	*	133.06	130.67	116.74	108.16	97.36	82.35	59.18	42.99	24.24	15.02	7.13	1.78
	4000	43.80	*	231.98	215.20	192.30	176.22	154.44	123.46	79.49	53.20	27.29	16.16	7.38	1.80
	6000	53.88	*	316.32	292.62	257.62	232.13	197.73	150.86	90.48	58.00	28.53	16.59	7.47	1.80
	8000	63.96	*	396.02	363.81	314.64	278.87	231.69	170.44	97.37	60.80	29.20	16.82	7.52	1.81
	10000	74.04	*	471.46	429.47	364.87	318.53	259.04	185.12	102.09	62.63	29.62	16.95	7.55	1.81
	12000	84.12	*	542.98	490.23	409.43	352.60	281.54	196.54	105.53	63.92	29.91	17.05	7.57	1.81
	14000	94.20	*	610.86	546.63	449.25	382.19	300.38	205.67	108.15	64.87	30.12	17.12	7.58	1.81
	16000	104.28	*	675.38	599.10	485.03	408.13	316.38	213.14	110.21	65.61	30.28	17.17	7.59	1.81
.100	2000	33.72	*	141.12	141.03	125.24	115.92	104.62	89.41	66.08	49.25	28.75	18.15	8.77	2.22
	4000	43.80	*	246.07	227.87	204.29	188.33	167.00	136.45	91.26	62.68	33.06	19.82	9.15	2.24
	6000	53.88	*	332.87	308.71	274.42	249.81	216.38	169.55	105.73	69.35	34.87	20.46	9.29	2.25
	8000	63.96	*	415.77	384.17	337.04	302.67	256.45	194.10	115.12	73.34	35.87	20.81	9.36	2.26
	10000	74.04	*	495.03	454.76	393.30	348.59	289.61	213.05	121.71	76.00	36.50	21.02	9.40	2.26
	12000	84.12	*	570.87	520.93	444.13	388.86	317.50	228.10	126.59	77.89	36.94	21.16	9.43	2.26
	14000	94.20	*	643.53	583.10	490.28	424.46	341.30	240.36	130.34	79.31	37.26	21.27	9.45	2.26
	16000	104.28	*	713.19	641.61	532.36	456.15	361.83	250.53	133.33	80.41	37.50	21.35	9.46	2.26
.080	2000	33.72	*	151.20	141.12	135.25	124.83	112.65	96.91	73.28	55.93	33.82	21.80	10.74	2.76
	4000	43.80	*	262.74	242.36	217.29	201.04	179.84	149.68	103.78	73.20	39.80	24.21	11.31	2.80
	6000	53.88	*	351.60	326.11	291.66	267.61	235.09	188.72	122.37	82.28	42.42	25.17	11.52	2.81
	8000	63.96	*	437.19	405.27	359.37	326.27	281.31	218.78	134.90	87.88	43.89	25.69	11.63	2.82
	10000	74.04	*	519.71	480.21	421.30	378.33	320.56	242.63	143.91	91.68	44.84	26.01	11.70	2.82
	12000	84.12	*	599.32	551.26	478.14	424.86	354.30	262.01	150.70	94.43	45.49	26.23	11.74	2.82
	14000	94.20	*	676.16	618.71	530.50	466.70	383.62	278.08	156.00	96.51	45.97	26.39	11.77	2.82
	16000	104.28	*	750.39	682.83	578.90	504.51	409.33	291.62	160.25	98.13	46.34	26.51	11.80	2.83

TABLE B.2 (Continued)

COSTS FOR EQUAL EFFECTIVENESS WITH STERILE MALES NATIVE FEMALES/SQ. MI.															
COMPETITIVE NESS	STERILE FLIES RELEASED	SWASS PROGRAM COST	*	200	160	120	100	80	60	40	30	20	15	10	5

.060	2000	33.72	*	168.00	154.56	151.20	138.70	124.69	107.58	83.12	65.16	41.20	27.34	13.87	3.65
	4000	43.80	*	268.80	264.85	236.40	219.02	197.29	167.24	120.84	88.20	50.04	31.11	14.82	3.71
	6000	53.88	*	380.36	351.66	315.41	291.35	259.52	214.00	145.63	101.28	54.17	32.69	15.17	3.73
	8000	63.96	*	468.79	434.81	388.88	356.82	313.45	251.63	163.16	109.70	56.56	33.56	15.36	3.75
	10000	74.04	*	554.79	514.52	457.36	416.35	360.64	282.58	176.22	115.59	58.12	34.11	15.48	3.75
	12000	84.12	*	638.44	591.00	521.35	470.73	402.28	308.47	186.32	119.93	59.21	34.48	15.55	3.76
	14000	94.20	*	719.84	664.43	581.28	520.60	439.29	330.45	194.37	123.26	60.03	34.76	15.61	3.76
	16000	104.28	*	799.09	735.01	637.52	566.48	472.40	349.35	200.93	125.90	60.66	34.97	15.65	3.76
.050	2000	33.72	*	181.44	165.31	163.61	149.32	133.68	115.20	89.80	71.40	46.37	31.36	16.25	4.35
	4000	43.80	*	282.24	282.06	250.47	231.84	209.24	178.83	132.16	98.49	57.49	36.30	17.54	4.44
	6000	53.88	*	383.04	370.47	331.97	307.33	275.47	230.34	161.28	114.64	62.91	38.44	18.04	4.47
	8000	63.96	*	492.14	455.73	408.58	376.66	334.00	272.90	182.53	125.36	66.12	39.64	18.30	4.49
	10000	74.04	*	579.95	538.00	480.75	440.56	386.10	308.64	198.72	132.99	68.24	40.40	18.46	4.50
	12000	84.12	*	665.74	617.42	548.83	499.63	432.77	339.09	211.47	138.70	69.74	40.93	18.57	4.50
	14000	94.20	*	749.59	694.16	613.17	554.40	474.82	365.34	221.76	143.14	70.87	41.32	18.65	4.51
	16000	104.28	*	831.54	768.34	674.08	605.33	512.90	388.20	230.25	146.69	71.74	41.61	18.71	4.51
.040	2000	33.72	*	201.60	181.44	161.28	164.86	146.59	125.79	98.64	79.52	53.22	36.84	19.62	5.38
	4000	43.80	*	302.40	282.24	270.50	249.66	225.30	193.82	146.56	111.86	67.64	43.60	21.49	5.52
	6000	53.88	*	403.20	397.27	354.61	328.54	295.94	250.85	181.27	132.30	75.07	46.67	22.23	5.57
	8000	63.96	*	525.49	484.72	434.58	402.08	359.68	299.36	207.56	146.39	79.60	48.42	22.63	5.59
	10000	74.04	*	615.18	569.66	510.73	470.83	417.50	341.12	228.16	156.70	82.65	49.55	22.87	5.61
	12000	84.12	*	703.19	652.22	583.31	535.23	470.18	377.45	244.75	164.56	84.84	50.34	23.04	5.62
	14000	94.20	*	789.58	732.48	652.58	595.68	518.37	409.34	258.38	170.75	86.49	50.92	23.16	5.63
	16000	104.28	*	874.39	810.54	718.75	652.53	562.63	437.56	269.79	175.76	87.79	51.37	23.26	5.63

TABLE B.2 (Continued)

COSTS FOR EQUAL EFFECTIVENESS WITH STERILE MALES NATIVE FEMALES/SQ. MI.															
COMPETITIVE NESS	STERILE FLIES RELEASED	SWASS PROGRAM COST	*	200	160	120	100	80	60	40	30	20	15	10	5

.030	2000	33.72	*	235.20	208.32	181.44	190.21	167.32	142.24	111.55	91.02	62.94	44.86	24.80	7.06
	4000	43.80	*	336.00	309.12	302.40	277.39	249.39	215.16	166.25	130.32	82.40	54.67	27.75	7.30
	6000	53.88	*	436.80	439.97	389.24	359.88	324.89	278.66	208.32	157.05	93.21	59.42	28.97	7.38
	8000	63.96	*	537.60	529.69	472.81	438.05	394.58	334.47	241.69	176.40	100.09	62.22	29.64	7.42
	10000	74.04	*	638.40	617.46	553.28	512.22	459.12	383.90	268.80	191.06	104.85	64.07	30.06	7.45
	12000	84.12	*	760.73	703.33	630.82	582.70	519.04	427.99	291.26	202.55	108.34	65.38	30.35	7.47
	14000	94.20	*	849.78	787.36	705.60	649.76	574.83	467.56	310.18	211.80	111.01	66.36	30.56	7.48
	16000	104.28	*	937.59	869.62	777.75	713.63	626.90	503.26	326.33	219.41	113.12	67.12	30.72	7.49
.020	2000	33.72	*	302.40	262.08	221.76	201.60	207.53	173.21	134.22	110.18	78.70	58.13	33.92	10.28
	4000	43.80	*	403.20	362.88	322.56	329.73	293.18	251.57	197.28	159.03	106.43	73.67	39.24	10.76
	6000	53.88	*	504.00	463.68	453.60	416.09	374.08	322.73	249.37	195.48	123.60	82.01	41.62	10.94
	8000	63.96	*	604.80	564.48	541.00	499.32	450.60	387.64	293.13	223.71	135.27	87.21	42.98	11.04
	10000	74.04	*	705.60	705.15	626.18	579.60	523.10	447.07	330.40	246.23	143.73	90.76	43.85	11.10
	12000	84.12	*	806.40	794.54	709.21	657.07	591.88	501.71	362.53	264.60	150.13	93.34	44.46	11.14
	14000	94.20	*	907.20	882.63	790.18	731.88	657.22	552.10	390.52	279.88	155.15	95.30	44.91	11.16
	16000	104.28	*	1050.98	969.43	869.17	804.17	719.37	598.72	415.11	292.78	159.19	96.83	45.25	11.19
.010	2000	33.72	*	504.00	423.36	342.72	302.40	262.08	261.95	194.88	157.88	114.55	87.85	55.44	19.01
	4000	43.80	*	604.80	524.16	443.52	403.20	415.06	346.42	268.45	220.37	157.40	116.26	67.85	20.56
	6000	53.88	*	705.60	624.96	544.32	570.64	501.95	426.72	334.66	273.05	188.83	134.57	74.41	21.19
	8000	63.96	*	806.40	725.76	645.12	659.46	586.37	503.15	394.56	318.07	212.87	147.35	78.48	21.53
	10000	74.04	*	907.20	826.56	818.07	746.62	668.40	575.98	449.02	356.99	231.84	156.78	81.24	21.74
	12000	84.12	*	1008.00	927.36	907.20	832.18	748.16	645.47	498.74	390.96	247.20	164.02	83.25	21.89
	14000	94.20	*	1108.80	1028.16	995.17	916.18	825.73	711.83	544.32	420.88	259.89	169.76	84.76	22.00
	16000	104.28	*	1209.60	1128.96	1082.01	998.65	901.21	775.27	586.25	447.42	270.55	174.41	85.95	22.08

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TABLE B.3

FLY COMPETITIVENESS		SWASS/ STERILE FLIES	STERILE FLIES ONLY	EFFECTIVENESS FOR EQUAL COSTS WITH STERILE MALES NATIVE FEMALES/SQ. MI.													
		FLIES		200	160	120	100	80	60	40	30	20	15	10	5		

.125	2000	6690	*	11/ 65	8/ 44	5/ 27	3/ 19	2/ 13	1/ 8	1/ 3	0/ 2	0/ 1	0/ 1	0/ 0	0/ 0		
	4000	8690	*	7/ 54	4/ 36	3/ 22	2/ 16	1/ 10	1/ 6	0/ 3	0/ 2	0/ 1	0/ 0	0/ 0	0/ 0		
	6000	10690	*	5/ 46	3/ 31	2/ 18	1/ 13	1/ 9	0/ 5	0/ 2	0/ 1	0/ 1	0/ 0	0/ 0	0/ 0		
	8000	12690	*	4/ 40	2/ 27	1/ 16	1/ 11	1/ 7	0/ 4	0/ 2	0/ 1	0/ 0	0/ 0	0/ 0	0/ 0		
	10000	14690	*	3/ 36	2/ 24	1/ 14	1/ 10	0/ 6	0/ 4	0/ 2	0/ 1	0/ 0	0/ 0	0/ 0	0/ 0		
	12000	16690	*	3/ 32	2/ 21	1/ 12	1/ 9	0/ 6	0/ 3	0/ 1	0/ 1	0/ 0	0/ 0	0/ 0	0/ 0		
	14000	18690	*	2/ 29	1/ 19	1/ 11	1/ 8	0/ 5	0/ 3	0/ 1	0/ 1	0/ 0	0/ 0	0/ 0	0/ 0		
	16000	20690	*	2/ 27	1/ 18	1/ 10	0/ 7	0/ 5	0/ 3	0/ 1	0/ 1	0/ 0	0/ 0	0/ 0	0/ 0		
.100	2000	6690	*	13/ 75	9/ 52	6/ 32	4/ 23	3/ 15	2/ 9	1/ 4	0/ 2	0/ 1	0/ 1	0/ 0	0/ 0		
	4000	8690	*	8/ 63	5/ 43	3/ 26	2/ 19	1/ 12	1/ 7	0/ 3	0/ 2	0/ 1	0/ 1	0/ 0	0/ 0		
	6000	10690	*	6/ 54	4/ 37	2/ 22	2/ 16	1/ 10	1/ 6	0/ 3	0/ 2	0/ 1	0/ 0	0/ 0	0/ 0		
	8000	12690	*	4/ 48	3/ 32	2/ 19	1/ 14	1/ 9	0/ 5	0/ 2	0/ 1	0/ 1	0/ 0	0/ 0	0/ 0		
	10000	14690	*	4/ 43	2/ 29	1/ 17	1/ 12	1/ 8	0/ 5	0/ 2	0/ 1	0/ 1	0/ 0	0/ 0	0/ 0		
	12000	16690	*	3/ 39	2/ 26	1/ 15	1/ 11	1/ 7	0/ 4	0/ 2	0/ 1	0/ 0	0/ 0	0/ 0	0/ 0		
	14000	18690	*	3/ 35	2/ 23	1/ 14	1/ 10	0/ 6	0/ 4	0/ 2	0/ 1	0/ 0	0/ 0	0/ 0	0/ 0		
	16000	20690	*	2/ 32	2/ 21	1/ 12	1/ 9	0/ 6	0/ 3	0/ 1	0/ 1	0/ 0	0/ 0	0/ 0	0/ 0		
.080	2000	6690	*	15/ 86	11/ 60	7/ 37	5/ 27	3/ 18	2/ 11	1/ 5	1/ 3	0/ 1	0/ 1	0/ 0	0/ 0		
	4000	8690	*	10/ 73	6/ 50	4/ 31	3/ 22	2/ 15	1/ 9	0/ 4	0/ 2	0/ 1	0/ 1	0/ 0	0/ 0		
	6000	10690	*	7/ 64	5/ 44	3/ 26	2/ 19	1/ 13	1/ 7	0/ 3	0/ 2	0/ 1	0/ 1	0/ 0	0/ 0		
	8000	12690	*	5/ 57	4/ 38	2/ 23	1/ 16	1/ 11	1/ 6	0/ 3	0/ 2	0/ 1	0/ 0	0/ 0	0/ 0		
	10000	14690	*	4/ 51	3/ 34	2/ 20	1/ 15	1/ 10	0/ 6	0/ 3	0/ 1	0/ 1	0/ 0	0/ 0	0/ 0		
	12000	16690	*	4/ 46	2/ 31	1/ 18	1/ 13	1/ 9	0/ 5	0/ 2	0/ 1	0/ 1	0/ 0	0/ 0	0/ 0		
	14000	18690	*	3/ 42	2/ 28	1/ 17	1/ 12	1/ 8	0/ 4	0/ 2	0/ 1	0/ 1	0/ 0	0/ 0	0/ 0		
	16000	20690	*	3/ 39	2/ 26	1/ 15	1/ 11	0/ 7	0/ 4	0/ 2	0/ 1	0/ 0	0/ 0	0/ 0	0/ 0		

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TABLE B.3 (Continued)

		EFFECTIVENESS FOR EQUAL COSTS WITH STERILE MALES NATIVE FEMALES/SQ. MI.															
FLY COMPETITIVE NESS	SWASS/ STERILE FLIES	STERILE * FLIES * ONLY *	200	160	120	100	80	60	40	30	20	15	10	5			

B-15	.060	2000	6690 *	18/100	13/ 71	8/ 45	6/ 33	4/ 23	2/ 14	1/ 7	1/ 4	0/ 2	0/ 1	0/ 0	0/ 0		
		4000	8690 *	12/ 87	8/ 61	5/ 38	3/ 28	2/ 19	1/ 11	1/ 5	0/ 3	0/ 1	0/ 1	0/ 0	0/ 0		
		6000	10690 *	9/ 77	6/ 53	3/ 33	2/ 24	2/ 16	1/ 9	0/ 4	0/ 3	0/ 1	0/ 1	0/ 0	0/ 0		
		8000	12690 *	7/ 69	5/ 47	3/ 29	2/ 21	1/ 14	1/ 8	0/ 4	0/ 2	0/ 1	0/ 1	0/ 0	0/ 0		
		10000	14690 *	6/ 62	4/ 43	2/ 26	2/ 18	1/ 12	1/ 7	0/ 3	0/ 2	0/ 1	0/ 0	0/ 0	0/ 0		
		12000	16690 *	5/ 57	3/ 39	2/ 23	1/ 17	1/ 11	0/ 6	0/ 3	0/ 2	0/ 1	0/ 0	0/ 0	0/ 0		
		14000	18690 *	4/ 53	3/ 36	2/ 21	1/ 15	1/ 10	0/ 6	0/ 3	0/ 2	0/ 1	0/ 0	0/ 0	0/ 0		
		16000	20690 *	4/ 49	2/ 33	1/ 19	1/ 14	1/ 9	0/ 5	0/ 2	0/ 1	0/ 1	0/ 0	0/ 0	0/ 0		
		.050	2000	6690 *	20/109	14/ 78	9/ 50	7/ 37	5/ 26	3/ 16	1/ 8	1/ 5	0/ 2	0/ 1	0/ 1	0/ 0	
			4000	8690 *	13/ 96	9/ 68	6/ 43	4/ 32	3/ 22	2/ 13	1/ 6	0/ 4	0/ 2	0/ 1	0/ 0	0/ 0	
			6000	10690 *	10/ 86	7/ 60	4/ 37	3/ 27	2/ 18	1/ 11	1/ 5	0/ 3	0/ 1	0/ 1	0/ 0	0/ 0	
			8000	12690 *	8/ 77	5/ 54	3/ 33	2/ 24	1/ 16	1/ 10	0/ 4	0/ 3	0/ 1	0/ 1	0/ 0	0/ 0	
			10000	14690 *	7/ 71	4/ 49	3/ 30	2/ 21	1/ 14	1/ 8	0/ 4	0/ 2	0/ 1	0/ 1	0/ 0	0/ 0	
			12000	16690 *	6/ 65	4/ 44	2/ 27	2/ 19	1/ 13	1/ 8	0/ 3	0/ 2	0/ 1	0/ 1	0/ 0	0/ 0	
			14000	18690 *	5/ 60	3/ 41	2/ 25	1/ 18	1/ 12	0/ 7	0/ 3	0/ 2	0/ 1	0/ 0	0/ 0	0/ 0	
			16000	20690 *	4/ 56	3/ 38	2/ 23	1/ 16	1/ 11	0/ 6	0/ 3	0/ 2	0/ 1	0/ 0	0/ 0	0/ 0	
	.040	2000	6690 *	22/120	16/ 87	10/ 57	8/ 43	5/ 30	3/ 19	2/ 9	1/ 5	0/ 3	0/ 2	0/ 1	0/ 0		
		4000	8690 *	15/107	11/ 77	7/ 49	5/ 37	3/ 25	2/ 15	1/ 7	1/ 4	0/ 2	0/ 1	0/ 1	0/ 0		
		6000	10690 *	12/ 97	8/ 68	5/ 43	3/ 32	2/ 22	1/ 13	1/ 6	0/ 4	0/ 2	0/ 1	0/ 0	0/ 0		
		8000	12690 *	10/ 88	6/ 62	4/ 39	3/ 28	2/ 19	1/ 11	0/ 5	0/ 3	0/ 1	0/ 1	0/ 0	0/ 0		
		10000	14690 *	8/ 81	5/ 56	3/ 35	2/ 25	1/ 17	1/ 10	0/ 5	0/ 3	0/ 1	0/ 1	0/ 0	0/ 0		
		12000	16690 *	7/ 75	5/ 52	3/ 32	2/ 23	1/ 15	1/ 9	0/ 4	0/ 2	0/ 1	0/ 1	0/ 0	0/ 0		
		14000	18690 *	6/ 70	4/ 48	2/ 29	2/ 21	1/ 14	1/ 8	0/ 4	0/ 2	0/ 1	0/ 1	0/ 0	0/ 0		
		16000	20690 *	5/ 65	4/ 45	2/ 27	1/ 19	1/ 13	1/ 8	0/ 4	0/ 2	0/ 1	0/ 1	0/ 0	0/ 0		

TABLE B.3 (Continued)

		EFFECTIVENESS FOR EQUAL COSTS WITH STERILE MALES NATIVE FEMALES/SQ. MI.														
FLY COMPETITIVE NESS	SWASS/ STERILE FLIES	STERILE * FLIES *		200	160	120	100	80	60	40	30	20	15	10	5	

B-16	.030	2000	6690 *	25/133	18/ 98	12/ 65	9/ 50	6/ 35	4/ 22	2/ 11	1/ 7	1/ 3	0/ 2	0/ 1	0/ 0	
		4000	8690 *	18/121	13/ 88	8/ 58	6/ 43	4/ 30	2/ 19	1/ 9	1/ 6	0/ 3	0/ 2	0/ 1	0/ 0	
		6000	10690 *	14/111	10/ 80	6/ 51	4/ 38	3/ 27	2/ 16	1/ 8	0/ 5	0/ 2	0/ 1	0/ 1	0/ 0	
		8000	12690 *	12/102	8/ 73	5/ 46	3/ 34	2/ 24	1/ 14	1/ 7	0/ 4	0/ 2	0/ 1	0/ 0	0/ 0	
		10000	14690 *	10/ 95	7/ 67	4/ 42	3/ 31	2/ 21	1/ 13	1/ 6	0/ 4	0/ 2	0/ 1	0/ 0	0/ 0	
		12000	16690 *	9/ 89	6/ 62	3/ 39	2/ 29	2/ 19	1/ 12	0/ 6	0/ 3	0/ 1	0/ 1	0/ 0	0/ 0	
		14000	18690 *	8/ 83	5/ 58	3/ 36	2/ 26	1/ 18	1/ 11	0/ 5	0/ 3	0/ 1	0/ 1	0/ 0	0/ 0	
		16000	20690 *	7/ 78	5/ 54	3/ 33	2/ 24	1/ 16	1/ 10	0/ 5	0/ 3	0/ 1	0/ 1	0/ 0	0/ 0	
		.020	2000	6690 *	29/150	21/113	14/ 77	11/ 60	8/ 44	5/ 28	3/ 15	2/ 9	1/ 5	0/ 3	0/ 1	0/ 0
		4000	8690 *	22/139	16/104	10/ 70	8/ 54	5/ 38	3/ 25	2/ 13	1/ 8	0/ 4	0/ 2	0/ 1	0/ 0	
		6000	10690 *	18/130	13/ 96	8/ 63	6/ 48	4/ 34	2/ 22	1/ 11	1/ 7	0/ 3	0/ 2	0/ 1	0/ 0	
		8000	12690 *	15/122	11/ 89	7/ 58	5/ 44	3/ 31	2/ 19	1/ 10	1/ 6	0/ 3	0/ 2	0/ 1	0/ 0	
		10000	14690 *	13/115	9/ 83	6/ 54	4/ 41	3/ 28	2/ 17	1/ 9	0/ 5	0/ 2	0/ 1	0/ 1	0/ 0	
		12000	16690 *	12/109	8/ 78	5/ 50	3/ 37	2/ 26	1/ 16	1/ 8	0/ 5	0/ 2	0/ 1	0/ 1	0/ 0	
		14000	18690 *	11/103	7/ 74	4/ 47	3/ 35	2/ 24	1/ 15	1/ 7	0/ 4	0/ 2	0/ 1	0/ 1	0/ 0	
		16000	20690 *	10/ 98	6/ 70	4/ 44	3/ 33	2/ 22	1/ 13	0/ 6	0/ 4	0/ 2	0/ 1	0/ 0	0/ 0	
	.010	2000	6690 *	33/171	26/132	18/ 94	14/ 75	11/ 56	7/ 39	4/ 22	3/ 14	1/ 7	1/ 5	0/ 2	0/ 1	
	4000	8690 *	29/164	21/126	14/ 88	11/ 70	8/ 52	5/ 35	3/ 19	2/ 12	1/ 6	0/ 4	0/ 2	0/ 1	0/ 1	
	6000	10690 *	25/158	18/120	12/ 83	9/ 65	6/ 48	4/ 32	2/ 17	1/ 11	1/ 5	0/ 3	0/ 2	0/ 0	0/ 0	
	8000	12690 *	22/152	16/115	10/ 78	8/ 61	5/ 45	3/ 29	2/ 15	1/ 10	0/ 5	0/ 3	0/ 1	0/ 0	0/ 0	
	10000	14690 *	20/146	14/110	9/ 74	7/ 58	5/ 42	3/ 27	1/ 14	1/ 9	0/ 4	0/ 3	0/ 1	0/ 0	0/ 0	
	12000	16690 *	18/141	13/105	8/ 71	6/ 55	4/ 39	2/ 25	1/ 13	1/ 8	0/ 4	0/ 2	0/ 1	0/ 0	0/ 0	
	14000	18690 *	17/136	12/101	7/ 67	5/ 52	4/ 37	2/ 23	1/ 12	1/ 7	0/ 4	0/ 2	0/ 1	0/ 0	0/ 0	
	16000	20690 *	15/132	11/ 97	7/ 64	5/ 49	3/ 35	2/ 22	1/ 11	1/ 7	0/ 3	0/ 2	0/ 1	0/ 0	0/ 0	

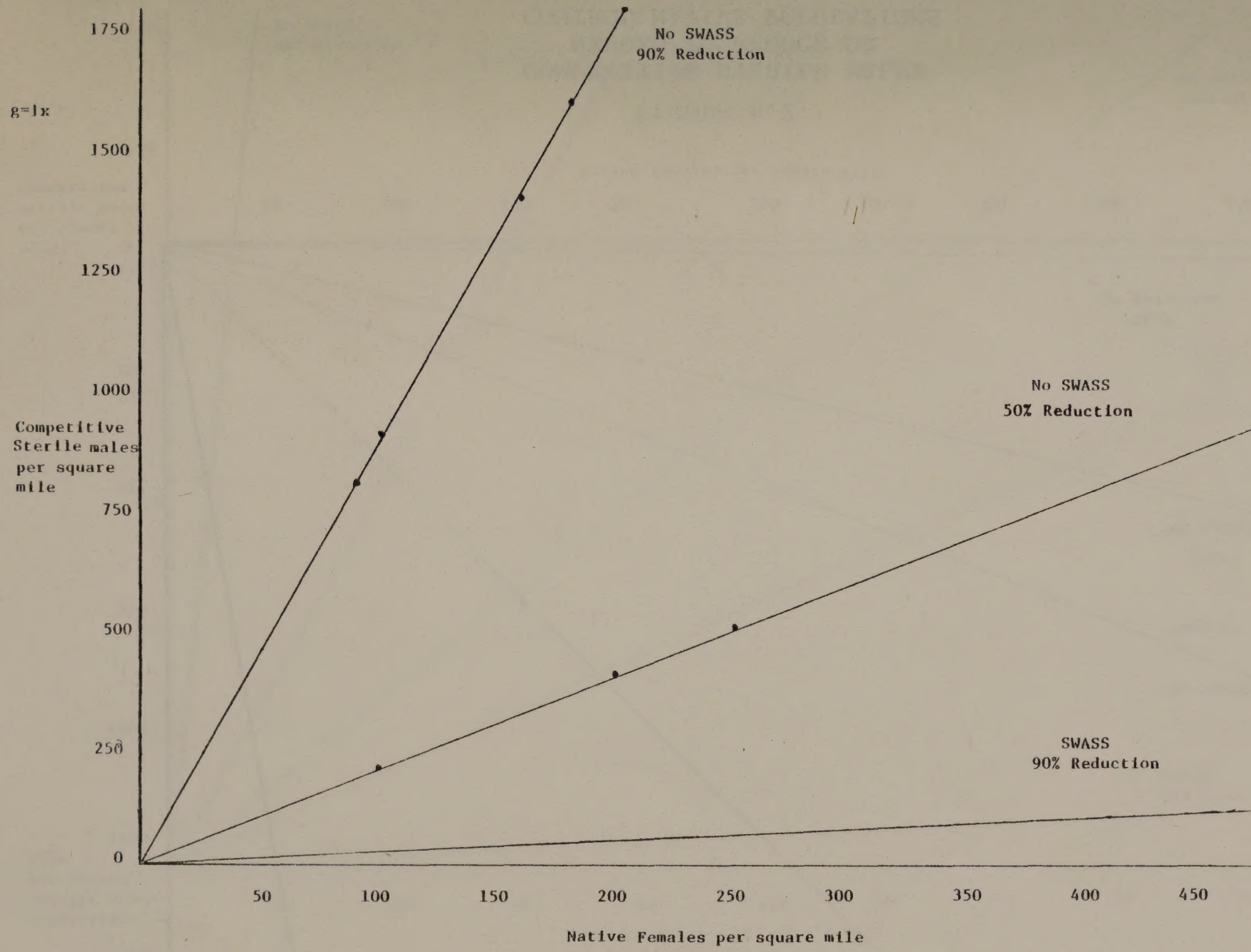


FIGURE B.1
COMPETITIVE STERILE MALES
NEEDED TO REDUCE OR
CONTROL NATIVE POPULATIONS
WITH AND WITHOUT SWASS

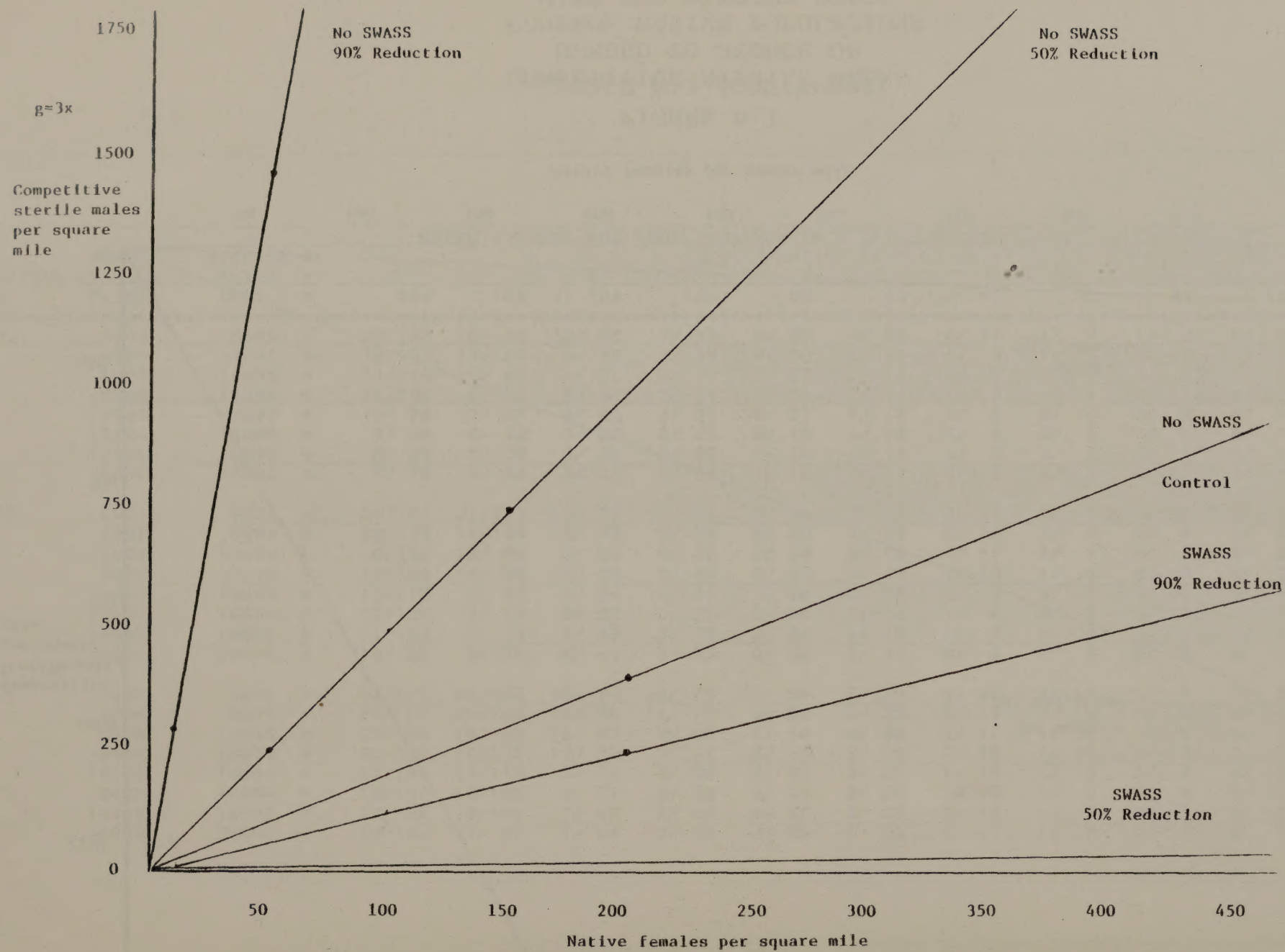


FIGURE B.2
 COMPETITIVE STERILE MALES
 NEEDED TO REDUCE OR
 CONTROL NATIVE POPULATIONS
 WITH AND WITHOUT SWASS

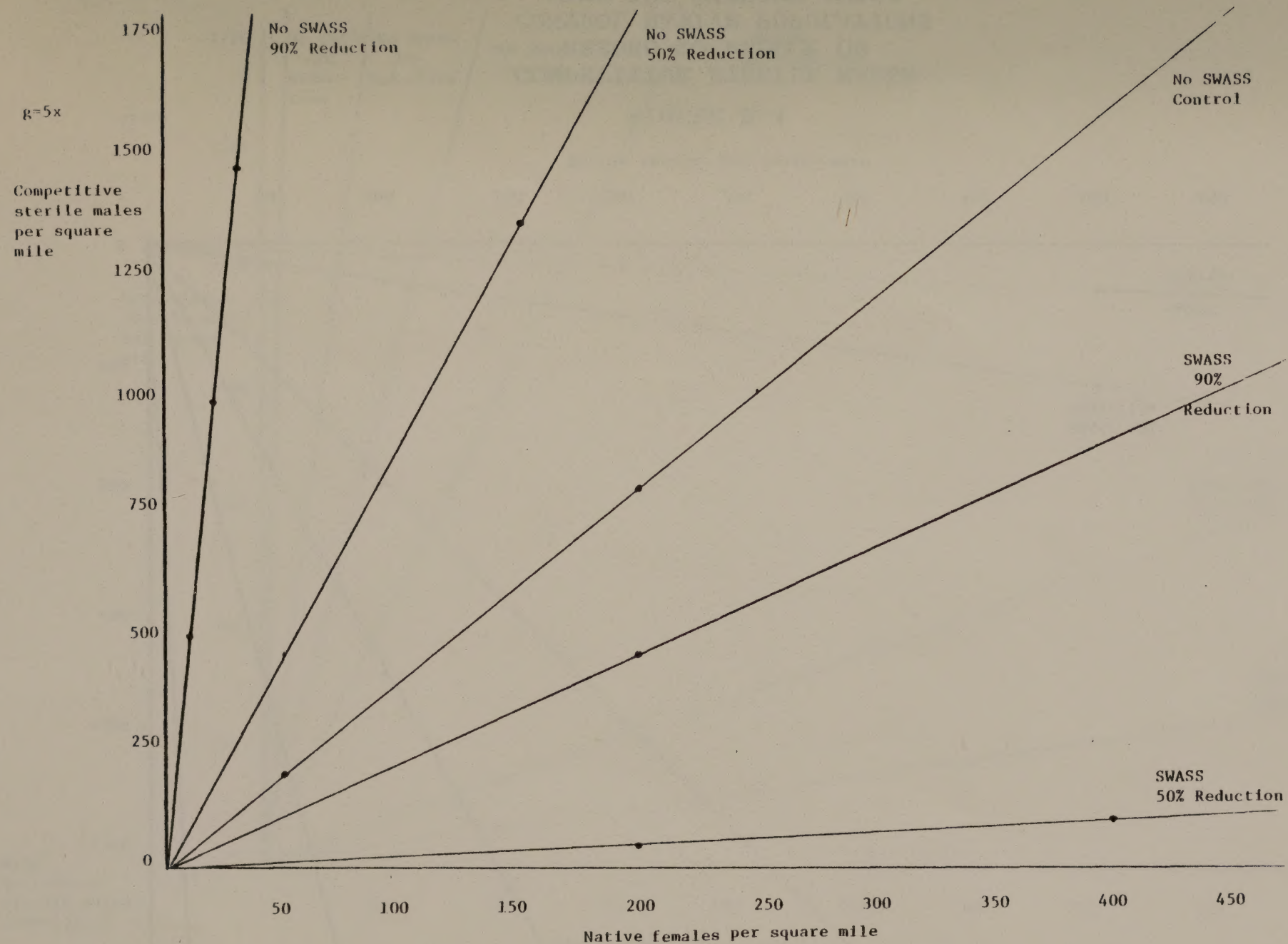


FIGURE B.3
COMPETITIVE STERILE MALES
NEEDED TO REDUCE OR
CONTROL NATIVE POPULATIONS
WITH AND WITHOUT SWASS

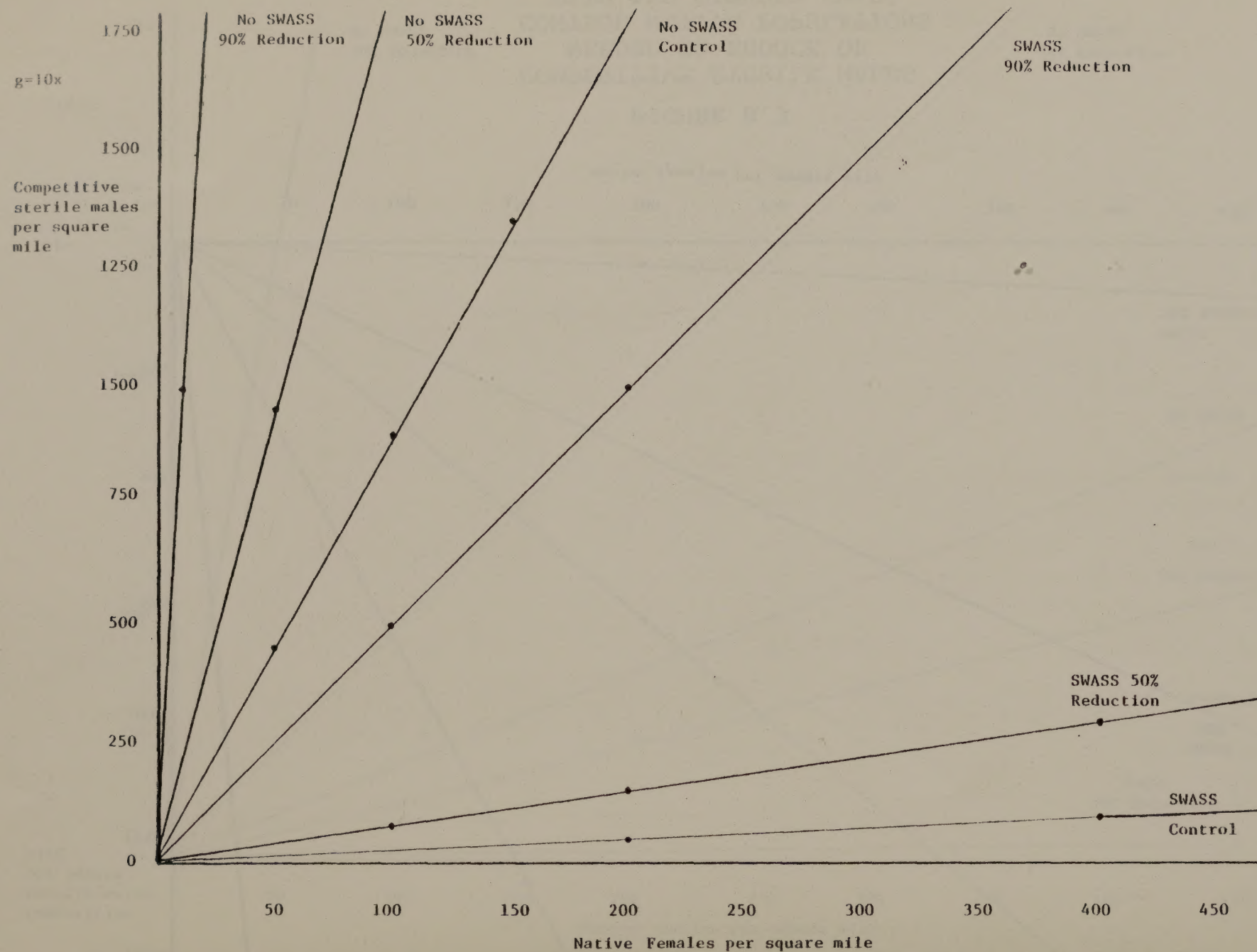


FIGURE B.4
COMPETITIVE STERILE MALES
NEEDED TO REDUCE OR
CONTROL NATIVE POPULATIONS
WITH AND WITHOUT SWASS

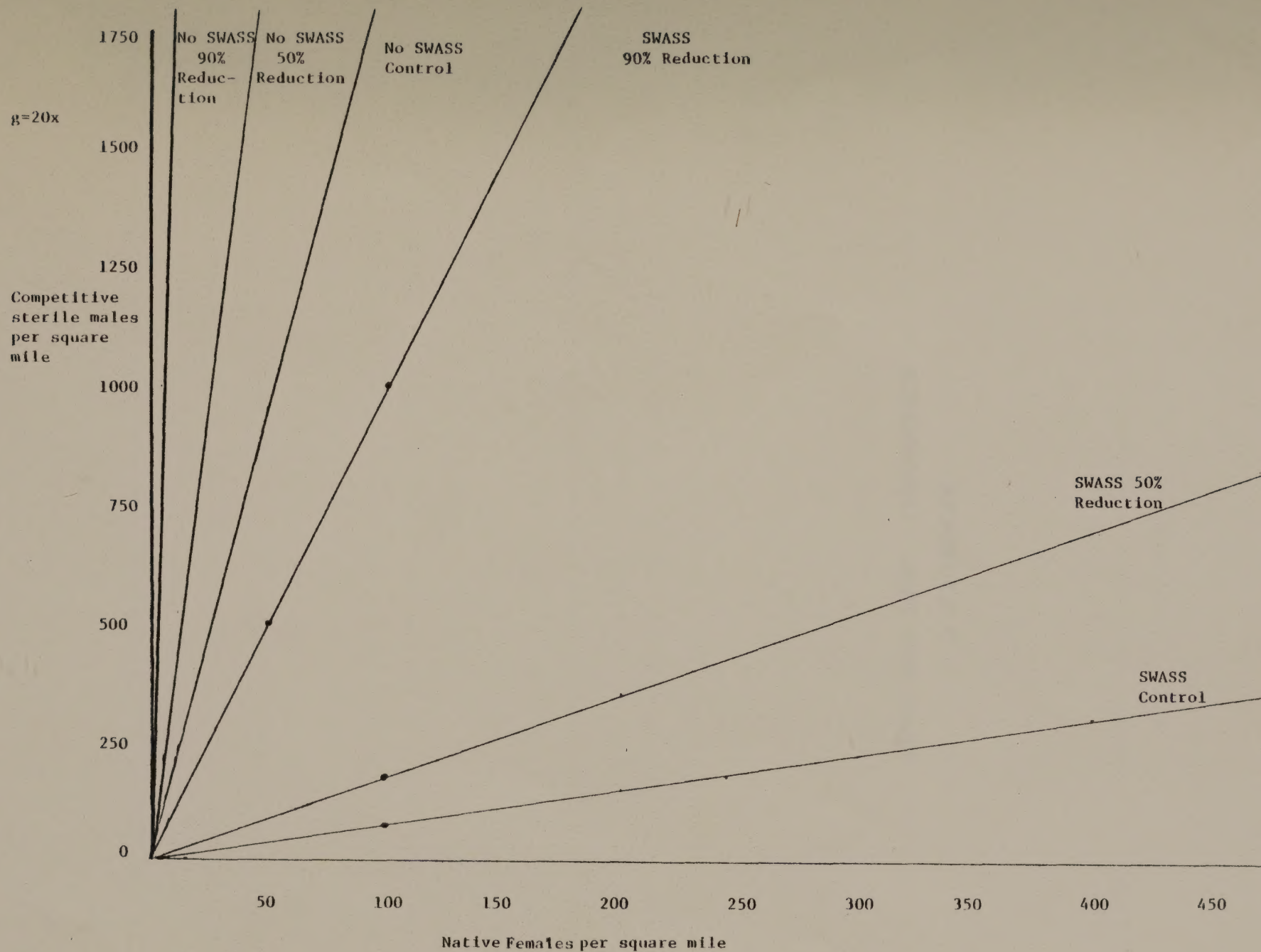


FIGURE B.5
COMPETITIVE STERILE MALES
NEEDED TO REDUCE OR
CONTROL NATIVE POPULATIONS
WITH AND WITHOUT SWASS

APPENDIX C
SCREWWORM: COST PER CASE

APPENDIX C
SCREWORM: COST PER CASE

C.0 Introduction

The ultimate objective of any program designed to reduce or eradicate screwworm populations is to eliminate the adverse economic impact of screwworm cases. The costs of screwworms are manifested in several ways and ultimately impact upon both producers and consumers of livestock products of the affected types of animals.

The most convenient and useful manner in which the benefit of alternative screwworm control programs can be assessed is through a direct measure of the cost associated with the particular incidence of screwworm associated with alternative programs. Under certain assumptions which will be discussed in the following section, an estimate of the average cost of a screwworm case can be devised. It then becomes a matter of projecting the approximate number of cases associated with alternative programs and of multiplying by the cost per case to find the cost associated with screwworm cases for alternative programs. The difference in the cost from the baseline program can be viewed as the benefit of the alternative under consideration. Subtraction of the cost of implementing the particular program would lead to the calculation of net benefit of the alternative under consideration. Comparison of the net benefits of alternative programs can provide an important basis for decision making. While there may be certain types of programs which can best be evaluated by methods not requiring the use of estimates of cost per case, it is expected that this will be an important element of the decision making process involving screwworm control programs.

The estimation of the current cost per case relied substantially upon an estimate made in 1976 through surveys of ranchers in areas of Texas which experienced significant screwworm outbreaks. Separate estimates were derived for cattle, and for sheep and goats combined. This survey identified the different components of the cost of screwworms. The different components can be categorized as loss in value or death animals, the cost of treating animals and the cost of finding infected animals. This effort used the estimates for 1976 in conjunction with updated information on the various components of the cost of screwworm to obtain an estimate of current (1979) cost per case.

While continued changes in the general price level are certain to be reflected in the costs of the various component costs of screwworms, no attempt has been made to project the future levels of these costs. The OMB requires that the evaluation of programs be based upon estimates of benefit and costs in terms of current price levels. Only if there is clear and demonstrable evidence that certain elements of costs or benefit will change in relative terms, are expected future prices to be taken into consideration. Because no reliable basis exists for projecting such changes in this case, no estimation of future levels of cost will be made.

C.1 Survey Methodology

A previous estimate of the cost per case for screwworm in 1976 [Texas Agricultural Extension Service, 1978] provided the basis for the derivation of an estimate of cost per case for 1979. Changes in the various types of costs resulting from screwworm cases were identified and the appropriate adjustments made in the 1976 estimate.

The methodology employed in the estimation of cost per case in 1976 is described briefly below, and the assumptions implicit in the use of the methodology will be discussed as the validity of the method is considered.

Following this, the procedures used in updating the 1976 estimate will be presented with a discussion of the implications of those procedures and a tabulation of the 1979 estimates.

The 1976 estimate was made through a survey of ranches following a screwworm outbreak. A representative sample of cattle, and sheep and goat ranches in areas of Texas in which screwworm outbreaks had been significant was chosen. Ranch personnel were interviewed and the types and levels of costs incurred as a result of the screwworm outbreak were identified. The following income and expenditure items were found to be significantly affected by the incidence of screwworm: death loss, loss at marketing, loss of weight, fuel and vehicle expense, medication and insecticides, and house and feed. The level of each of these types of costs were estimated for the ranches and then divided by the number of cases in order to derive the average levels of such cost per screwworm case.

There are a number of assumptions of interest in the calculation of an estimate in this manner and in its use as a basis for estimating screwworm costs in other areas. First, it is implicit that the response of producers in other areas will, on the average, approximate the response of the producers surveyed. This is a realistic assumption because the areas in which the screwworm is generally prevalent are not greatly dissimilar, the ranching practices (primarily cow-calf operations) are generally similar and because the actions which must be taken to treat a screwworm case are essentially the same regardless of location.

Second, the levels of the various components of costs are assumed to be equal to those of other areas. These costs are not expected to vary considerably because the affected items are constrained in their regional variation by their mobility and relatively low transportation costs.

Third, it is assumed that the impact of the screwworm is not sufficiently great to substantially affect the price of cattle. The effectiveness of current control measures and the limited distribution of outbreaks in the past make it highly unlikely the screwworm damage and mortality could substantially effect the price of cattle in what is essentially a national market.

C.2 Update Methodology

The estimate derived by survey was updated through the use of data indicating the changes in the various types of cost that have occurred from 1976 through 1979. This estimate will be for 1979 prices because the most recent information is for that year. The use of a 1979 estimate may tend to understate the actual cost of screwworm at present due to the rapid increases in certain types of costs. The estimates of cost per case of screwworm in 1976 are shown below.

In order to estimate the levels of the different types of costs in 1979, data on the specific levels of those costs were obtained from several sources. The proportionate change in those prices from 1976 through 1979 was estimated through the use of data furnished by the Texas Agricultural Extension Service and by the U. S. Department of Agriculture. The changes in costs associated with weight loss, loss at marketing and death loss were estimated with the use of the proportionate change in the farm level prices for cattle and sheep in Texas.

The fuel and vehicle expense change was also estimated through the use of actual price changes in Texas over the period. Changes in labor costs, medical and insecticide costs, and house and feed costs were estimated by a review of projected budgets for the areas affected by screwworm for 1976 and 1979. The 1976 cost estimates, the estimates of proportionate change in those costs from 1976 through 1979 and the 1979 estimates of cost per case are shown in Table 1 for cattle and Table 2 for sheep and

goats. The data sources for the 1976 estimates and for the proportionate changes in the different types of costs are indicated by footnotes.

CATTLE

	<u>1976¹</u>	<u>Ratio 1979:1976</u>	<u>1979 Estimate</u>
Death Loss	33.64	2.335 ^{2,3}	78.54
Loss at Market	14.67	2.335 ^{2,3}	34.25
Weight Loss	8.70	1.20 ⁴	12.71
Labor	10.59	2.335 ^{2,3}	20.31
Fuel & Vehicle	8.31	1.67 ^{2,3}	13.88
Med. & Insect.	5.02	1.00 ⁴	5.02
House and Feed	<u>.63</u>		<u>.63</u>
Total	\$81.51		\$165.35

1. Texas Agricultural Extension Service, Texas A & M University System, Memorandum to County Extension Agents Regarding Current Status of Screwworm Program, Section on Economic Impact of Screwworm Program by Jesse Coche and Larry Ziphe, June 2, 1978.
2. Crop Reporting Board, Statistical Reporting Service, USDA, "Agricultural Prices Annual Summary 1976", June 1977, Pr 1-3(77).
3. Crop Reporting Board, Economics, Statistics and Cooperative Service, USDA, "Agricultural Prices", January through December 1979, Pr 1 (1,...12-79).
4. Texas Agricultural Extension Service, Texas A & M University System, "Estimated Costs and Returns", Projected 1976-1977 and Projected 1978-1979.

SHEEP AND GOATS

	<u>1976¹</u>	<u>Ratio 1979:1976</u>	<u>1979 Estimate</u>
Death Loss	\$16.27	1.9545 ^{2,3}	\$31.80
Loss at Market	2.66	1.9545 ^{2,3}	5.20
Weight Loss	1.33	1.33 ⁴	8.39
Labor	6.31	1.9545 ^{2,3}	2.60
Fuel & Vehicle	1.99	1.67 ^{2,3}	3.32
Med. & Insect.	2.99	1.00 ⁴	2.99
House and Feed	<u>1.00</u>	1.00 ⁴	<u>1.00</u>
Total	\$32.38		\$55.30

1. Texas Agricultural Extension Service, Texas A & M University System, Memorandum to County Extension Agents Regarding Current Status of Screwworm Program, Section on Economic Impact of Screwworm Program by Jesse Coche and Larry Ziphe, June 2, 1978.
2. Crop Reporting Board, Statistical Reporting Service, USDA, "Agricultural Prices Annual Summary 1976", June 1977, Pr 1-3(77).
3. Crop Reporting Board, Economics, Statistics and Cooperative Service, USDA, "Agricultural Prices", January through December 1979, Pr 1 (1,...12-79).
4. Texas Agricultural Extension Service, Texas A & M University System, "Estimated Costs and Returns", Projected 1976-1977 and Projected 1978-1979.

APPENDIX D

POPULATION DYNAMICS

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The first order population dynamics model used by Knippling to describe the screwworm fly population under a sterile male program is:

$$N_{i+1} = g_i \frac{N_i^2}{N_i + S_i}, \text{ where}$$

N_{i+1} = number of native females per square mile for the $(i+1)^{st}$ generation,

N_i = number of native females per square mile for the i^{th} generation,

S_i = number of sterile males released per square mile per application during the i^{th} generation, and

g_i = growth rate for i^{th} generation.

However, if an integrated pest management program is used, integrating SWASS and sterile flies, a modified equation must be used. In addition, a factor for the competitiveness of the sterile males is incorporated in the equation. The following variables will be added to the equation:

f = SWASS effectiveness on female flies (percentage of female flies killed by SWASS),

m = SWASS effectiveness on male flies (percentage of male flies killed by SWASS), and

e = competitive factor for sterile male flies
(ratio of native flies to sterile flies to
obtain 50% sterility of egg masses).

Since SWASS kills flies in the i th generation, the number of native females in the i th generation must be multiplied by $(1-f)$ to yield the number of native females remaining to mate. SWASS tends to kill fewer male flies than female flies, so a different multiplier, $(1-m)$, is used for the sterile males released in the i th generation. The competitiveness factor, e , is used to reduce the number of sterile males released to the effective number of competitive flies released.

The following equation is used in our analysis of the SWASS/sterile male program.

$$N_{i+1} = g_i \frac{((1-f)N_i)^2}{(1-f)N_i + e(1-m)S_i}$$

